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Applications of the Electric Balance to the Continuous Solution of Mathematical Formulae. PERRY A. BORDEN

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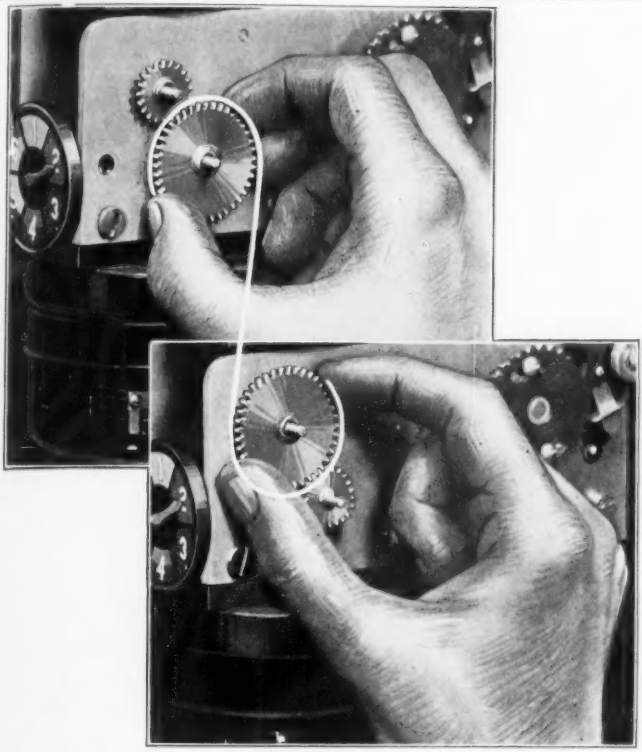

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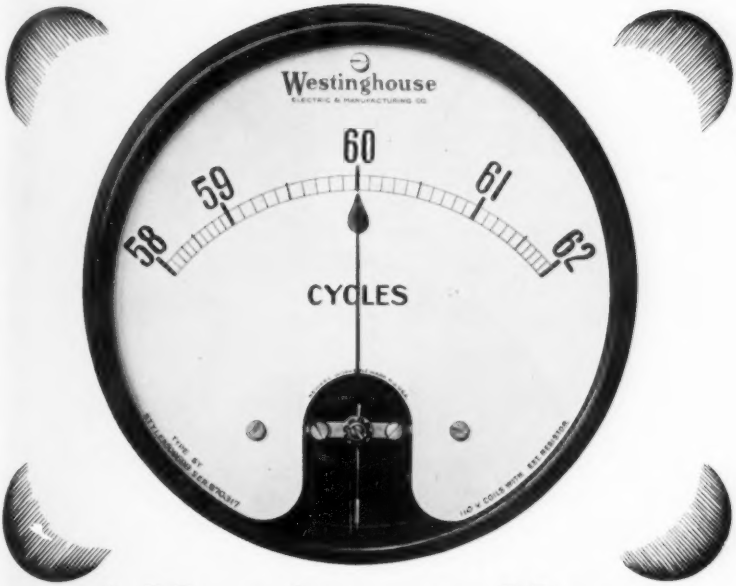

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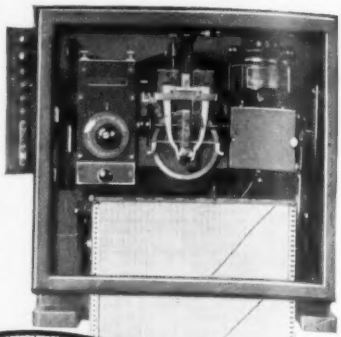

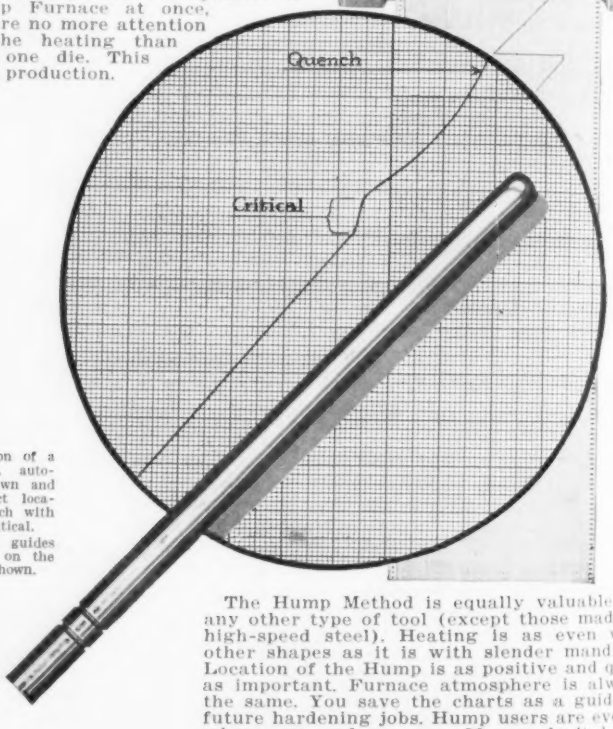

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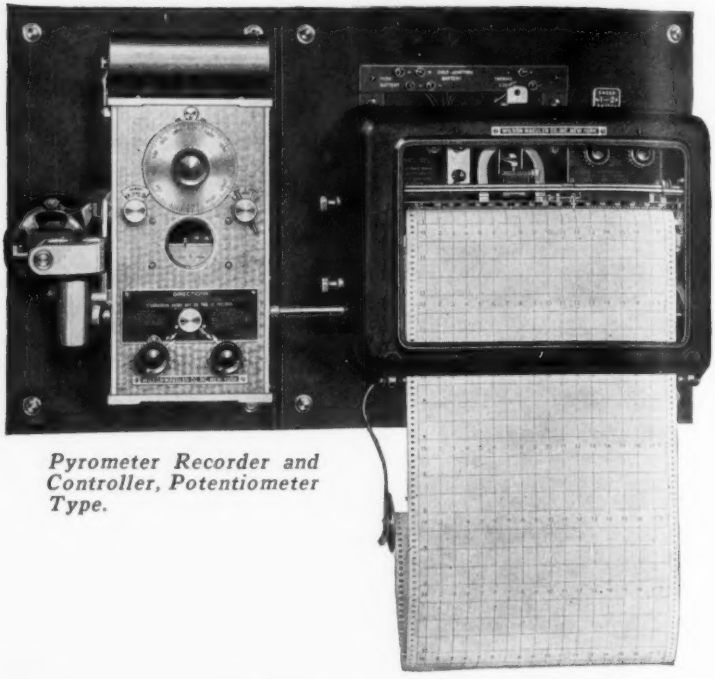

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Vol. 2, No. 12 DECEMBER, 1929 Pittsburgh, Pa.

To Our Readers

THE editor announces the following staff change.

M. F. Béhar is now Engineering Editor of INSTRUMENTS. He is a graduate of Pratt Institute of Technology in Industrial Mechanical Engineering, later continuing his studies at Columbia University.

Mr. Béhar has had a very extensive experience in the field covered by INSTRUMENTS. After 22 months with the American Expeditionary Forces, he served on the Technical Staff of the Chief of Ordnance in Washington, specializing in ballistic tests and development of small arms and ammunition. In the course of his service with the Army Ordnance Department he invented several devices, on some of which the Department took out covering patents, naming him as the inventor.

For more than 5 years he was with the C. J. Tagliabue Manufacturing Company, and during that time he had occasion to write articles for the technical press, also booklets on industrial applications of instruments.

Mr. Béhar was author by invitation of the article "Regulation, Automatic" in the new 14th Edition of Encyclopedia Britannica and collaborator on several other articles pertaining to industrial instruments. He also contributed the 75 page section on "Industrial Instruments and Their Uses" in the forthcoming revised edition of Rogers' "Manual of Industrial Chemistry."

Beginning in the January issue, the first installment of a series of articles will appear under the caption "Engineers' Handbook of Industrial Instruments," this to be prepared by Mr. Béhar. The need for such information has long been felt by engineers and practical production executives.

It is suggested that all readers of INSTRUMENTS call this announcement to the attention of the interested engineers and superintendents in their companies as the editor is certain that they will not want to miss a single installment of this important series.

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THE January issue will contain the following articles, any one of which will be worth the subscription price of $2.00. Use the enclosed subscription card.

DR. FOSTER DEE SNELL—*Recent Advances in Colorimetry.*

DR. W. G. BROMBACHER—*Aircraft Instruments.*

E. S. LINCOLN—*Electrical Instrument Developments.*

DR. S. R. WILLIAMS—*An Early Use of Magnetism for Mechanical Testing.*

M. F. BEHAR—*Temperature Instrument Developments in 1929.*

ARTHUR SCHRODER—*Developments in Laboratory Apparatus During 1929.*

DR. WALTER BLOCK—*Measurements—Industrial and Scientific.*

In the January issue will appear the first installment of a series of articles entitled "Engineers' Handbook of Industrial Instruments." This series when printed in book form will sell at about $5.00—Send in your subscription immediately.

The February issue will be entirely devoted to Calorimetry. In addition to the following articles:

DR. S. W. PARR—*Calorimetry in America.*

W. E. STACKHOUSE—*Calorimetry, Its Importance and Practice in the Gas Industry.*

it will contain descriptions of the calorimeters available to-day.—You cannot afford to miss this issue. The price of this issue will be $1.00.—Send in your subscription now.

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Some Improvements in Balance Design

J. T. Nichols

DURING recent years the so-called elastic knife edge has been used in a number of balances built for special purposes. It has certain advantages which recommend it for general use in balance construction. The use of a movable rider driven by a micrometer screw offers a means of doing away with the handling of small fractional weights in balance manipulation. In a few cases, where the desired sensitivity was not too great, reversing electric motors have been used to accomplish the balancing of screw-driven riders automatically. Here we have three innovations which have been tried out in special purpose balances but have not yet been applied to the design of balances intended for general use.

The advantages to be obtained by the use of these new ideas are:

1. Great ruggedness and reliability due to the elimination of sharp knife edges. It is a simple matter to design elastic knife edges so that, even if broken, they can be replaced without affecting the accuracy or sensitivity of the balance.
2. Faster manipulation due to the screw-driven rider.
3. Automatic operation in cases where the sensitivity desired is not too great. Semi-automatic operation a possibility in all cases.
4. Lower cost.

No attempt will be made to discuss mechanical details of construction here since the possible combinations are almost unlimited and the choice of constructional details and methods depends on the results desired and the equipment available. The advantages of these new ideas will be discussed in a general way and a schematic design incorporating all three ideas will be included.

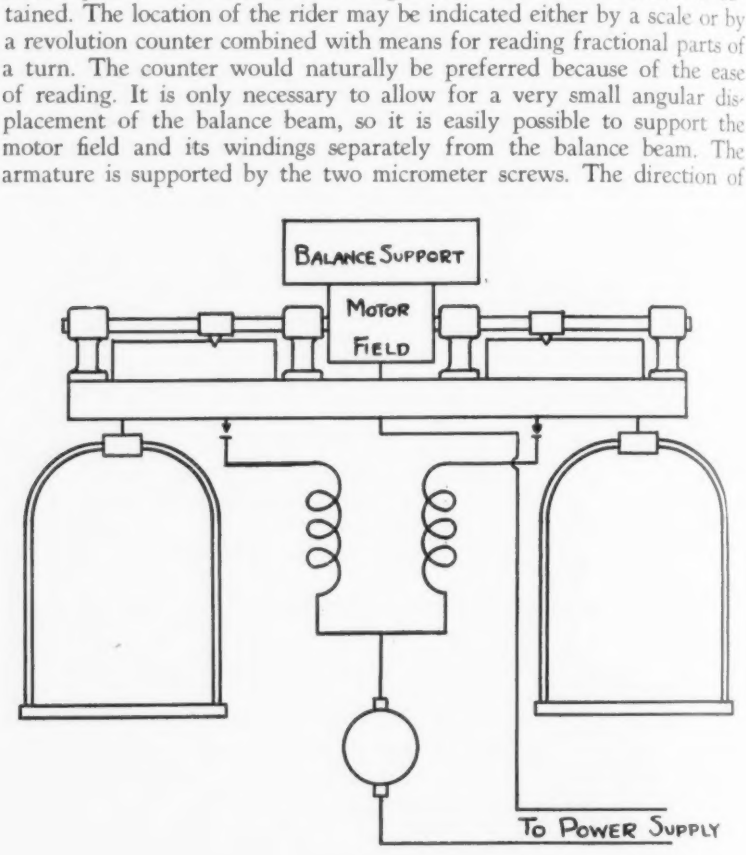
Of course it is possible to use only the elastic knife edge, using conventional design for the remainder of the balance. This change alone will produce a much more reliable and rugged instrument than is possible using the conventional type of knife edge.

The next step is to apply the screw-driven rider to the beam. This is only possible because of the ruggedness of the elastic knife edge and it eliminates the use of the smaller fractional weights or, when a lesser sensitivity will satisfy the requirements, the use of weights in balancing can be entirely avoided. The result is a considerable increase in the speed of weighing.

When it is desired to further increase the speed of balance operation the use of a reversing electric motor to operate the screw-driven rider is recommended. In order to keep the natural period of vibration of the balance within reason the armature of the motor should be made integral with the micrometer screw. The motor field and its windings can then be separately supported and, for convenience, two windings should be supplied, one for each direction of rotation. Suitable push-button switches may be provided to operate the motor by hand, or, if the sensitivity requirements are not too high, contacts may be arranged on the

balance beam so as to cause the motor to balance automatically. Balances constructed in this way have great possibilities for rapid, accurate weighing.

The illustration gives a schematic diagram of an automatically-balanced, motor-driven, screw-driven-rider type of balance. In this case two micrometer screws, one right-handed, the other left-handed, are used with two riders of slightly different weights. When the motor turns the two riders travel in opposite directions and the effect of moving one rider equal to the difference in weight of the two actual riders is obtained. The location of the rider may be indicated either by a scale or by a revolution counter combined with means for reading fractional parts of a turn. The counter would naturally be preferred because of the ease of reading. It is only necessary to allow for a very small angular displacement of the balance beam, so it is easily possible to support the motor field and its windings separately from the balance beam. The armature is supported by the two micrometer screws. The direction of



rotation of the motor is controlled by connecting one field winding in series with the rotor for clockwise rotation and the other field winding for anticlockwise rotation. This is done by contacts attached to the balance beam and, in this way, the balancing is done automatically. When greater sensitivities are required than can be obtained by this method the contacts may be removed from the balance beam and operated by push-button switches. A mirror reflecting a ray of light can be used to obtain a more sensitive indicator than the usual pointer.

Applications of the Electric Balance to the Continuous Solution of Mathematical Formulae

*Perry A. Borden**

BETWEEN any two associated electrical conductors there exists a mutual reaction directly proportional at any instant to the product of the strengths of the magnetic fields produced by the currents in the respective conductors. This condition maintains so long as the relative position of the two conductors is fixed and the distribution of the field fluxes remains unchanged. The principle is exemplified in such instruments as the Siemens dynamometer and the Kelvin balance. Since the field produced by an electric current in a circuit having no associated iron is directly proportional to the value of the current, it follows that, in all quantitative conceptions of torque magnitudes in such instruments, the conceptions of *current* and *field* may be used interchangeably.

The following statements, then, become axiomatic:—

(1) In the association of 2 electrical circuits, the mutual reaction is proportional to the product of the currents in the respective circuits. (a, Fig. 1) Whence—

(2) Between 2 electrical circuits carrying the same current, or currents proportional to one another, the reaction is proportional to the square of the current. (b, Fig. 1)

(3) Between 2 electrical circuits carrying currents proportional respectively to the voltage across the terminals of a system and the current in that system, the reaction is proportional to the watts in that system. (c, Fig. 1)

(4) In the association of an electrical circuit with a permanent magnet, the reaction is directly proportional to the value of the current in the circuit.

The first-named type of element, known as the "electrodynamic," is shown diagrammatically at A, Fig. 1, there being two fixed and opposed "pancake" coils, between which lies a movable coil, attached to the swinging arm of the balance. The fixed coils are usually connected in series; and the movable coil may or may not be in circuit with them, according to the type of connection in use. With current flowing in both circuits, the reaction is in the nature of an axial thrust upon the movable coil, which develops into a torque about the center of rotation of the balance arm. The second type of element, commonly known as the d'Arsonval, is illustrated at B. Fig. 1. While this element may take any one of a variety of forms, that shown has been chosen for simplicity of representation. One pole of a permanent magnet is surrounded by the movable coil, which tends to move axially along the magnet, its direction depending upon that of the current in its winding in relation to the polarity of the magnet. It is evident that, while the electrodynamic element is operative on either direct or alternating current, the d'Arsonval element delivers a sustained torque on direct current alone.

In the standard types of torsion dynamometer and electric balance, since the actuating torques are opposed by mechanical forces proportional to the deflection of the restoring element, it follows that the final measure of the electrical quantity is represented by a physical deflection, and that this deflection is proportional either to the quantity or to the square

*The Bristol Co., Waterbury, Conn.

of the quantity, according to the nature of the associated electrical circuits.* By a suitable combination of contacts and control mechanism, such a device may be made self balancing; and by the attachment of a pen to the restoring gear, there may be obtained a graphic record of the current, voltage or power under measurement. This application is found in a number of well-known types of recording instruments.

If the weight or spring in an instrument of the balance type be replaced by an electromagnetic source of opposing force, it is evident that great flexibility in the relative proportions of measured and observed quantities at once becomes available; and by combinations of different types of elements it becomes possible to obtain recorded solutions of the values of quantities which vary in accordance with more or less involved laws. An application of this principle is found in the "current" system of transmitting and recording power readings, wherein the torque of a Kelvin balance type of wattmeter is opposed by that of a permanent-magnet moving-coil element, in which the current is regulated through the medium of a control gear actuated by contacts on the balance. Since the torque of the latter element is directly proportional to the current in the electrical circuit, while that of the former is in proportion to the watts in the measured circuit, it follows that there flows in the d.-c. circuit a current at all times proportional to the power in the measured circuit. This is a combination illustrated in Fig. 1.

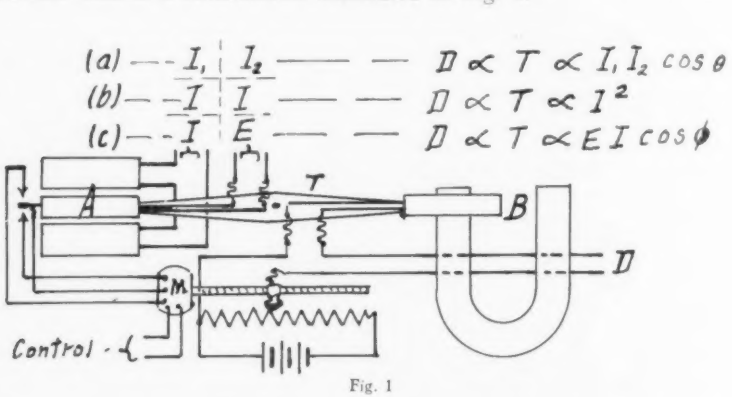


Fig. 1

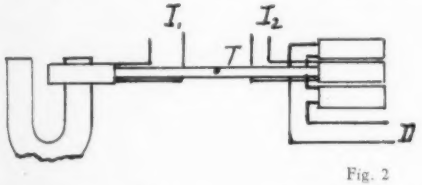
In general, it may be said that the basic principle of such a system consists in producing through the agency of electric currents a mechanical reaction whose value is a function of the quantity or quantities under measurement, and balancing the force of this reaction by an equal and opposite reaction produced through the agency of a derived current. Before entering upon an analysis of the arrangements by which mathematical processes may be carried out, there are given a few notes explanatory of the accompanying diagrams. Fig. 1 shows in some detail the arrangement of one transmitting unit of the "current system" of remote metering. A and B are respectively electrodynamic and d'Arsonval types of elements, balanced on an arm which is pivoted at an intermediate

*In spring-opposed instruments, this law is subject to certain modifications.

point. (In the actual instrument there are usually two electrodynamic elements for the measurement of polyphase power.) Through contacts on the balance arm the motor M is actuated, operating a rheostat of the potentiometer type, and regulating a battery current through the element B in such a sense as to oppose the deflection of the arm and restore the system to equilibrim. This battery current, which is known as the "derived current" (D), may be passed through other measuring circuits, forming a link in a chain of metering elements. In the other diagrams the detail of the control mechanism are omitted, and the derived currents, indicated by D_1, D_2 etc., considered as being under control of the torques T_1, T_2 etc. on the respective balance arms.

Products. Since the fundamental principle of the electrodynamic element is that the torque be proportional to the product of the currents flowing in the respective circuits, it follows that, in order to obtain a product, it is necessary only to represent the magnitude of the two quantities to be multiplied together by currents in these circuits. If these be alternating currents in phase agreement or direct currents, the true product is at once obtained. If they be alternating currents of the same frequency but out of phase, the torque will be proportional to the product of the two currents and the cosine of the time-phase angle between them. In the wattmeter, the currents are proportional to and in phase with the line current and voltage respectively, giving a torque, and hence a derived current in proportion to the value of the power in the measured circuit.

Ratios. For the purpose of obtaining ratios, the balance is arranged so that the total torque is proportional to the quantity which forms the numerator of the fraction. The restoring force is produced by an electrodynamic element, carrying in its circuits currents respectively proportional to the denominator of the fraction and to the derived current. The arrangement is shown in Fig. 2. Since the numerator is proportional



$$D I_2 \propto T \propto I_1$$
$$\therefore D \propto \frac{T}{I_2} \propto \frac{I_1}{I_2}$$

Fig. 2

to the product of the derived current and the denominator, it follows that the derived current represents the ratio which exists between the numerator and the denominator.

Powers. When two circuits in an electrodynamic element carry the same current, or currents both in proportion to the one quantity, the derived current in a d'Arsonval element will vary as the square of the first-named current or the quantity which it represents. If this derived current be passed in turn through a second electrodynamic element, the process will be repeated, and a torque or second derived current obtained, varying as the fourth power of the original quantity.

If, instead of a d'Arsonval element, an electrodynamic element be used for the derived current on the first balance arm, the square of the

derived current will be proportional to the torque; and hence its value will be directly proportional to the original current. Third powers may therefore be obtained by combining in the 2 circuits of an electrodynamic element derived currents proportional respectively to the original quantity and to its square, the resulting reaction representing their product, and therefore the cube of the original quantity. This arrangement is shown in Fig. 3. It thus becomes possible to obtain a value proportional to any desired whole power of a current, voltage or quantity represented thereby.

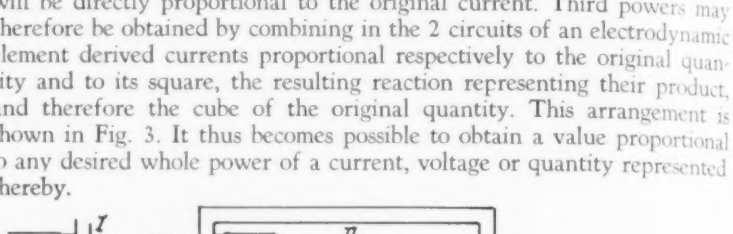


Fig. 3

Roots. The process for obtaining roots is basically the reverse of that for obtaining powers. Opposing the torque on the balance arm by a derived current through an electrodynamic element, this current becomes proportional to the square root of the torque, and therefore of the current or other quantity represented by it. And by repeating this combination there is obtained a value representative of the fourth root of the original quantity. Cube roots are obtained by a slightly different arrangement, shown in Fig. 4. The quantity measured is opposed by an electro-

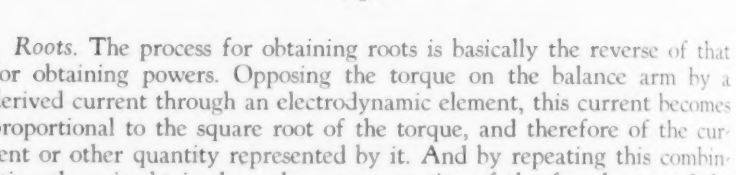


Fig. 4

dynamic element carrying 2 currents, one of which is under control of the first balance arm and is passed through a single-circuit electrodynamic element on the second arm. The torque thus produced on the second arm is opposed by the other of the above mentioned 2 currents, flowing in a d'Arsonval element, this current being under control of the second balance. By this means the square of 1 current is kept proportional to the value of the other, and their product to the original quantity. Thus, it will be seen that the first derived current (that which passes through the electrodynamic element on the second arm) is proportional to the cube root of the measured quantity, while the second derived current is proportional to its 2/3 power.

Sums and Differences. Since the total torque on the balance arm represents the algebraic sum of all the reactions exerted upon it, it follows that where the algebraic sums of quantities are required it is necessary only to represent them by reactions and apply to a balance arm, opposing them by a d'Arsonval element, when the derived current becomes proportional to the desired value. If, then, the algebraic sum of alternating currents is desired, they may be balanced by proportional direct currents and these added, either by interconnecting or by applying to a balance arm in d'Arsonval elements. If the sum of the squares of several currents is desired, it is necessary only to apply to the arm the torques produced by these currents in electrodynamic elements.

When the value desired is the vectorial sum of a number of alternating currents, the simplest method is to parallel these in one winding and measure the resultant. If this is not practicable they may be combined in a multiple-primary current transformer. If however, it be necessary to make the summation in a balance, a special construction is required, having for the several currents superimposed windings on both fixed and movable parts. The torque so obtained is proportional to the square of the resultant of the currents, and may be treated by any of the methods described in previous sections.

Trigonometrical Functions. In the introduction of trigonometrical functions into a system of calculations it is assumed that there is available a physical movement through an angle corresponding to that whose function is to be incorporated in the formula. Such being the case, there are several ways of representing the angular function by a current or force upon the balance arm. There may be attached to the moving part a device similar to an induction regulator, giving a current representative of the cosine of the angle of rotation from a certain fixed point; or as in Fig. 5, the permanent magnet of a d'Arsonval type of movement may be so mounted as to rotatable about an axis through the line of the conductors in its field. What probably constitutes a simpler and more accurate construction consists in the use of a uniform slide-wire associated with the moving part through a mechanical linkage suited to the desired function, and connected to the balance circuit by a system similar to that shown in Fig. 6 and described in the following paragraph.

Translation of the Measured Quantities. In those instances where the quantities to be measured are of an electrical nature they may usually be treated directly in the balance element without any mechanical interposition. The quantity which best lends itself to measurement is, of course, a direct current, which, when associated with a permanent magnet, produces a torque directly proportional to itself. The same applies to wattage, when measured in an electrodynamic element. If the quantity under measurement is an alternating current it may either be treated as such or translated into a direct current of proportional value, as in the upper balance arm shown in Fig. 3. Where it is desired to make one quantity proportional to a linear motion, such as a gate-opening or a water-level indicator, the logical method is to associate with the moving part a rheostat (preferably connected as a potentiometer), and cause it to control the current in the measuring element. Since, however, any current taken from the tapped point of such a rheostat will tend to destroy

the proportionality, the design of a suitable control device becomes intricate and subject to error caused by line conditions. In such a case, therefore, it is better to have the potentiometer type of rheostat regulate a voltage derived from a constant potential source, and oppose this voltage to the drop produced by the derived current in a fixed potentiometer. Such an arrangement is shown in Fig. 6. If the motion which it is desired to represent be of a rotary nature the moving part may be either directly

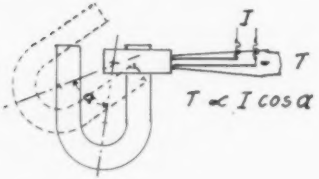


Fig. 5

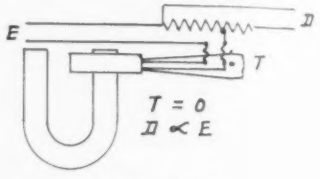


Fig. 6

connected to the rheostat, or engaged therewith through a linkage for giving trigonomtrical relationships, as suggested in the preceding paragraph. Non-linear relationships, such as that between the displacement and the area of opening of a valve or gate, may be corrected for by the use of potentiometer-type resistance cards with calculated contours. It may here be noted that where the variable follows a definite mathematical law, if a resistance card of negligible thickness be used, having one side straight, the equation of the curve representing the other side of the card will take the form of the first derivative of the varying quantity. Where velocities are concerned, it is possible to represent the speed by a counting device, making electrical contacts at a frequency proportional to the velocity, and intermittently charging a condenser, which in turn is discharged through the measuring circuit. This arrangement provides a direct current whose mean value is directly proportional to the frequency of the contacts, and therefore to the velocity.

The Introduction of Constants. The introduction of constant quantities and their adjustment for different specific problems is a very simple matter. Where the quantity under measurement is a voltage, supplying current directly into the measuring circuit, the constant is controlled by the value of the circuit resistance. If it be a voltage translated into a current through the medium of a fixed potentiometer the constant may be regulated by adjustment of the potentiometer setting. In the event of the measured quantity being a current, the constant will be subject to the number of turns in the actuating coils; and in the case of direct current, it may be controlled by a suitable shunt across the measuring circuit. In the electrodynamic element a simple way of adjusting the strength of action is found in altering the spacing of the current coils; and, with this in view at the time of design, a very effective micrometer adjustment can be introduced in the construction of the measuring element.

Interpretation of the Results. The final result of the calculation embodied in any of the arrangements which have been described is found in the form of a mechanical torque or a derived current, and these quan-

tities may be treated in a variety of ways. The torque may be made to operate a recording mechanism, such as is found in a number of types of graphic instruments, and give on a chart a permanent graphic record of results of the measurement and computation. Or, by utilizing the derived current, the record may be made at a remote point, and if desired, totalized with results of a number of similar measurements. If instantaneous values only are required, the derived current may be measured in an indicating ammeter, while if the current be passed through an ampere-hour meter the registration on the dials furnishes a mathematical integration of the solution of the formula, between any selected limits of time.

Some Applications of the System. The essentials of the system described have already found a number of applications, among which may again be mentioned the relay type of recording ammeter, voltmeter, and wattmeter, as well as the Pierce current-balance for transmitting power measurements. There has been developed by the writer and put into practical use a method of measuring the volt-amperes in an alternating current system, wherein 2 sets of electrodynamic elements measure the watts and the reactive component respectively, these quantities being squared and added, the square root of the result extracted and expressed in the form of a direct current;—this being proportional to the desired quantity. Another application lies in the measurement of power factor. There are available formulae for both balanced and unbalanced loads, which express the *tangent* of the equivalent phase angle of the load in the form of the ratio of 2 quantities, both easily measurable in elements of the electrodynamic wattmeter type. By measuring these values and applying them to a ratio-measuring combination, the result obtained represents the tangent of the angle whose cosine is desired. If the scale of the final recording mechanism be graduated in terms of the power factor represented by the values obtained, it will be found that this scale, while not uniform, has a very desirable proportionality. A continuous measurement of the actual or equivalent resistance of a circuit may be made by combining the voltage and the current in the system in a ratio-measuring unit, when the value of the result becomes proportional to the resistance or to the conductivity of the circuit, according to the scheme of connections employed.

While it would seem that this system of measurement, in the hands of the electrical engineer has possibilities limited (like those of the slide-rule) only by the user's ingenuity, and that it could be developed in a variety of forms, suited either to installation in the power house or in the engineering office, yet its principal application appears to lie outside the field of electrical engineering, and in those branches of work, such as hydraulic, where rather involved formulas are continuously being encountered. For example, there may be mentioned a type of flow meter, making use of a V-notch, the flow varying as the 5/2 power of the depth of the stream. By means of the system described this quantity can be converted into a linear quantity, thus enabling totalization, as well as transmission of readings. The system also lends itself to recording the values obtained in flow measurement by Pitot or Venturi tubes; and in the measurement of gaseous media. It becomes a simple matter to introduce compensation for specific gravity or pressure. In electrical flow

meters, such as the Thomas or King types, the derived electrical quantities may in a similar manner be incorporated in formulae. For determining the flow through hydraulic turbines, the measured current may be placed under control of the gate mechanism; and if the section area of the water passages is not proportional to the deflection of any part, correction can be made by the use of a specially designed rheostat, as explained in an earlier paragraph. This value, combined with a quantity representative of the head on the turbine, provides data for obtaining a derived current directly proportional to the flow of water; and by a summation of a number of these currents, to the total diversion through a power house or a system of power houses. Where there are required integrations beyond the practical range of the system under discussion, many of the problems can be handled by combining this system with the Continuous Integraph developed by Professor Bush.

Reference has already been made to the use of a counting contact as a basis of measuring velocity; and if the velocity be of a rotational nature, the electrical system is readily applicable to a number of types of centrifugal tachometers. There have been developed several transmission dynamometers, in which an electric current is made proportional to the torque upon the shaft. By combining this current in an electrodynamic element with another proportional to the velocity there is obtained a reaction representative of the value of power transmitted. By balancing this value through a ratio measuring combination against the electrical output of a generator (or input to a motor), there is obtained a continuous measure of the efficiency of the electrical unit; or by expressing the relationship as a difference, rather than as a quotient, the result appears as a record of the losses in the apparatus.

The recording and integrating possibilities of the electrical method render it highly desirable for use with continuous weighing and measuring machines, such as are used for grain, fuel and crushed minerals. By coupling the weight and velocity characteristics of such apparatus, there is obtained a simple and accurate means of determining the consumption and cost of such materials; and by applying the principle outlined in the preceding paragraph to the fuel input and power output of an electrical plant, over-all efficiency or losses may be made the basis of a continuous measurement.

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Measurements
Industrial & Scientific
An Instruction Book for Engineers

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CHAPTER I (*Cont'd*)

The Historical Development of the Measuring Science and the Systems of Length and Weight

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4. THE SHAPE OF THE UNITS

(a) Shape of Units of Length, End Standards and Line Standards. End standards are units of length in which the entire length is represented by the distance between two limiting faces; they are called line standards if the distance between two limiting lines represent the entire length. For end standards, rod and unit have the same length, for the line standards, the division is usually not carried out to the end of the rod which in most cases projects beyond both ends of the unit of length. In commerce, i.e., for the measures of long dry goods, in industry, i.e., for folding rules, and also in the scales used in the shop, measures are frequently used in which one edge of the limiting face at the same time serves as limit for a division on one surface. Such measures are called line end standards. For more precise scales, such combinations are generally avoided and pure end standards and pure line standards are preferred because the adjustments for faces, edges, and lines have different accuracies. The first embodiment of the meter, the French Archives meter, is an end measuring standard, the second embodiment, the International meter prototype, a line standard. On the contrary, the first prototype in Prussia made under the statute for weights and measure of May 16, 1816, having a length of three feet, was a line standard, the second made in 1835 was an end standard. The prototype of the yard is a line standard. From this it can be seen that there were different opinions in different countries and at different times as to the suitability of the two types, at least for units of the greatest accuracy. At present, the metrological science prefers line-standards, the geodesists, surveyors, etc., however, cannot do without end standards, and industry also uses them more and more frequently especially recently, in addition to the line-measures, particularly if a greater accuracy is required.

The simplest form of an end measure is a rod of any section which is cut perpendicular to its axis at its ends. The end-faces over their

whole surface form the limits of the total length. As an example may be mentioned the Archives meter. The German prototype of the meter, until the year 1884, legally representing the meter-unit had the same shape. It was procured in 1817 through Alexander von Humboldt from Fortin in Paris and has, as Fig. 3 shows, a rectangular section 25.8 by 5.65 mm. This rod was, compared with the Archives meter for the first time in 1817 by Arago and Humboldt, and again in 1863 by Brix, Morin and Regnault, and was found to be longer by 0.00301 mm. at the temperature of melting ice. The difference of the two rods is given to one hundred-thousandth of a millimeter (0.01μ) but actually, measuring rods of this shape will generally be applied with advantage only where accuracies of about one tenth of a milliameter are required.

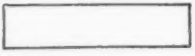

Fig. 3. Section of the old Prussian meter.

The measures of length are used for determining the straight-line distance between points. It could, therefore, be expected to represent them by material lines, as this can not be done, to give them at least as small a section as possible in order to also obtain limiting faces of as small extent as possible. But one can not go too far in this respect as otherwise the deflections of the measures become too great and too irregular to permit reliable measurements. A compromise must be made so that the limiting faces have a certain area. Under certain conditions this might even be of advantage as they can then be used anywhere on their surface, and that they are used so, is shown, i.e., by the condition of the limiting faces of the Archives meter which show impressions over a great part of its end-faces. One could imagine all such measures to consist of a very great number of uni-directed elementary rods which are combined into one body. Each elementary rod has its own total length. If all total lengths are to exactly agree with one another their limiting points on both sides must be in one plane, or, what is the same, the limiting faces of the measuring rod must be: 1. absolutely smooth, 2. absolutely parallel, 3. absolutely perpendicular to its axis. From this requirement it follows further that when making a measurement this axis must be laid in the direction of the straight line to be measured so that those points of the end faces, which are used, are located exactly opposite each other, that means, belong to the same elementary rod. If the axis of the rod forms an angle with the mentioned line the distance obtained is too long.

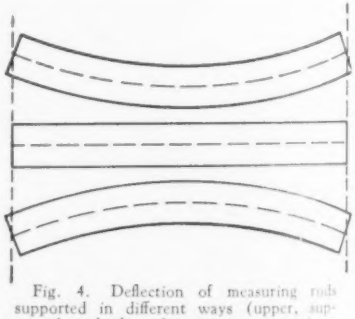

Fig. 4. Deflection of measuring rods supported in different ways (upper, supported at both ends; center supported on plane surface; lower, supported in center).

Three requirements are therefore placed on an end standard: 1. The measuring body must not show a deflection, 2. the limiting faces must be plane-parallel and at right angles to the axis of the rod, 3. an oblique position should be impossible.

The first condition can, apparently, be easily fulfilled because if the section of the body is made sufficiently large no deflection whatever will occur. Unfortunately, a limit is very soon reached here as the rod, with increased thickness, becomes too heavy and unwieldy. On the other hand, one has at least succeeded, by the following reasoning, to reduce the influence of the deflection to a minimum. If a rod as illustrated in Fig. 4, has a deflection downwards the distance of two points on its upper surface will decrease, the distance of two points on the under surface increase. If the rod deflects upwards conditions are reversed. But in both cases the rod suffers in its center layer represented by the dotted line as shown in the figure, only a very insignificant shortening in the axis of the rod, never a lengthening. This layer is called the neutral layer or the neutral plane. As a rule, the deflection does not follow such a simple course, the rod assumes different shapes, according to whether it is supported over its whole length or only in a few points; but its change of length is always least in the neutral plane. In order to be independent of the influences of deflection as much as possible, the section of the body of an end standard will therefore, be made, on the one hand, as strong as possible or of suitable shape, on the other the limiting faces or also the body as a whole will be shaped so that it can be used only in the neutral plane proper or at least very close to the latter. Finally, a material of sufficient strength will be selected for the measure, which is also necessary to protect the end-faces against external impressions especially against impacts. This and the means which are applied to limit the effects of deflection during the use and comparison of the standards will be discussed below.

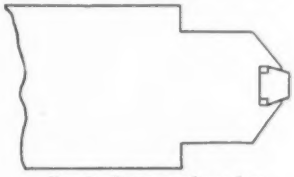

Fig. 5. Diagram of one form of a precision end meter with jewel inserted as limiting face (full size).

As a rule, a rectangular section (square or parallelogram) or a circle is chosen as the shape of end-standards.

The fundamental end standard of the meter, however, has the same X-shaped section as the prototype (line-standard) of the meter. This shape automatically assures measurements only being made close to the neutral plane. For the other section shapes one can not very well speak of a neutral plane since its position changes with the position of the rod. The length of the rod is, therefore, generally considered as the distance of the end-points of the axis in which the neutral planes intersect, and precautions are taken to actually measure only in the axis. Accordingly if greater stress is laid on the greatest protection against impacts or against oblique position of the rods in comparisons this is accomplished by marking the axis especially at the end-faces or by having them project from the end-faces.

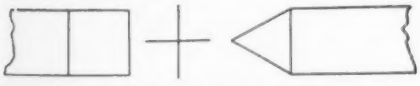

Fig. 6. Diagram of a measurement with a measure having knife-shaped edges.

If the first method is chosen it is sufficient to mark a circle around the axis as a center on the plane end-face. In fact, Bessel did this when making the Prussian fundamental unit of three feet and its replicas. The fundamental measure made to his specifications by the mechanic Th. Baumann in 1835 is a cast iron rod of square section 9 lines (19.62 mm.) on a side. Into the ends conical shaped holes increasing in diameter towards the inside are drilled, into which are inserted truncated circular sapphire cones in a gold setting. The end-faces are then ground with the sapphire cones and polished so that the sapphires appear in the end faces as small circles which have the axis as center. The details of the construction can be seen from Bessel's paper.[4] In the replicas of the prototype, cones of hardened steel were used in place of the sapphire cones. The protection against side impacts is complete here, protection against front impacts lies in the hardness of the material (jewel, hardened steel) but an oblique position is not excluded as marking of the axis of the rod alone is not an absolute assurance against improper use.

One of Baumann's replicas has been further improved by the mechanic C. Reichel in the following manner: The measuring body of square section was turned down at both ends so that two cylinders of 28 mm. length and 18.5 mm. diameter were obtained. This cylinder was then again turned down so that only a small cylinder of about 6.8 mm. and 1.2 mm. height remained. In the centers of the end-faces sapphire cones of 3 mm. length having a slight taper were inserted which are bounded on both ends by plane surfaces and ring-shaped zones of spherical shape. The external boundary surfaces have a diameter of 3 mm. Each end of the body forms a cavity exactly fitted to the jewel, the bottom of the cavity is provided with an axial depression only touching the jewel in a ring which assures an intimate contact. As Fig. 5 shows, the originally cylindrical projection of the measuring body is pressed over the spherical zone of the jewel in such a manner that the sapphire cone is held in the steel body with great pressure. Finally, the end-faces are accurately ground parallel by a special method. The details can be obtained from the description by Loewenherz.[5] With this manner of forming the standard the danger of an oblique position is almost entirely avoided, but the protection against impacts from the side receives less consideration.

In the Archives meter and the International prototype, as also in the rods of Bessel, Baumann and Reichel, the shaping of the end faces is naturally given the utmost care in order to fulfill the second condition; the rods of Bessel, especially, however, those of Reichel deserve preference because the smaller the end-surface the less the defects in the plane-parallelism of the faces and their position with reference to the axis of the rod can influence the measurements.

In certain surveyor's measuring rods the measuring body has a rectangular section but the ends have knife edges so arranged that the edge falls in the neutral plane. The center of the edges is, as a

[4]Darstellung der Untersuchungen und Massregeln, welche in den Jahren 1835 bis 1838 durch die Einheit des preussischen Langenmasses veranlasst worden sind. F. W. Bessel, Berlin 1839.

[5]Loewenherz: Bericht über die wissenschaftlichen Instrumente auf der Berliner Gewerbeausstellung 1879.

rule, specially marked. If the two end-faces are placed so that they form a right angle to each other their edges intersect in the axis. The rods are of steel with hardened ends. Taken by itself, this solution seems to be the best because here the length of the unit seems to be determined by a line. Actually, rods with knife-edged ends are used only for such measurements in which the requirements of accuracy do not exceed a few hundreds of a millimeter. If greater accuracy is to be obtained, edges and axis of the rod must be located in the same horizontal or vertical plane. Further, the edges must also lie in planes parallel to each other and vertical to the first-named plane. These conditions are difficult to meet especially with larger sections of the measuring body, and it is usually satisfactory to fulfill them approximately since the above mentioned shapes have fully proved their worth for high-grade measuring rods (Fig. 6).

With the end standards must be classed, in addition to the measuring rods just discussed, also certain kinds of gages. The mode of

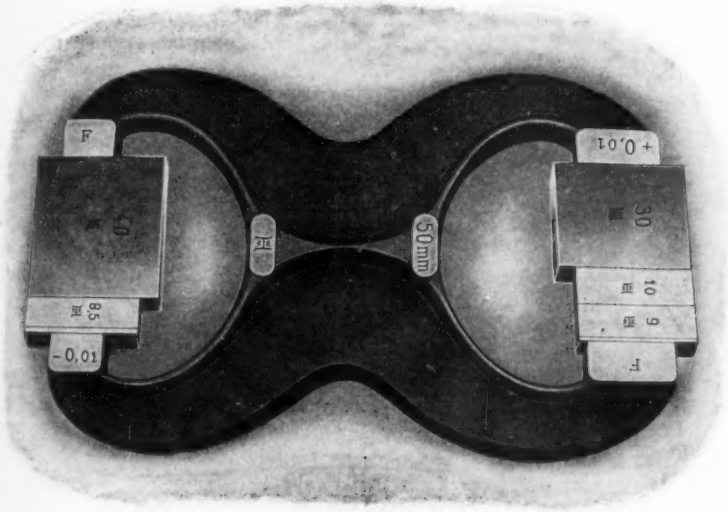

Fig. 7. Steel gage blocks put together for checking a snap gage.
(30 mm + 10 mm + 9 mm + 1.01 mm = 50.01 mm
40 mm + 8.5 mm + 1.49 mm = 49.99 mm)

designation varies. The difference between measuring rods and gages, however, lies in that the measuring rods must conform to a certain measuring system with respect to their length while the length represented by gages can be anything and is only determined by the purpose of its application. Guillaume[6] defines as end standards (étalons à bouts), also such gages which not only serve for the measurement of the distance between two points but at the same time for checking the course of surfaces (cylindrical holes, slots, etc.). He distinguishes three

[6]Ch. Ed. Guillaume: L'état actuel de la question des étalons a bouts. Appendix to the report of the meeting of the International Committee on Weights and Measures, 1909.

principal forms: the cylinder which gives the value of length by the diameter; the rod, with spherical shaped end-faces; and the disc with plane-parallel end-faces. The first class are the gage pins, but the measuring-discs also belong here, as also the plug gages. Whether the definition of end measure is still applicable to these gages seems doubtful. With the same right all gages for checking odd sections could be designated as end measures as they all have the same purpose, to determine whether the distance of planes is exactly uniform and whether the course of surfaces remains within the required accuracy. On the other hand, end measuring rods with spherical ends which are used for pieces of large diameter in the place of gage pins and plug gages can also be used for measuring distances. They generally have a circular cross-section and are tapered at the ends. Since the center of the sphere coincides with the center of the axis the measurement is always carried out along one of its diameters; an oblique position of the rod therefore has no influence on the result which is a great advantage for this application, where the rods are held in the hand. The deflection can, however, be rather disagreeable especially as the rod, when used, is only supported in the center.

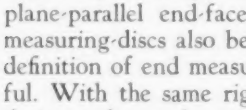

Fig. 8. Longitudinal section through a line-meter by Kater. The limiting line is at a.

The discs with plane-parallel end-faces, also called gage blocks are rectangular pieces with rectangular cross-section and different thicknesses. The material is carbon-steel. The limiting faces are glass-hard and highly polished. The parallelism of the two measuring faces is accomplished by a special process so accurately that the thicknesses at different parts of the surfaces differ by only a few thousandths of a millimeter (tenth of a micron). Also the nominal values are true to a few tenths of a micron. Planeness and polish of the surfaces are so perfect that the measures shoved (not placed) on one another with slight pressure adhere to each other without force. (Fig. 7.) They are supplied in sizes of 0.5 to 100 mm. in steps down to 0.001 mm. The first of such sets of gage blocks was made by Johansson (Eskilstuna, Sweden), but they are now manufactured by several firms. By putting together several gage blocks all sizes up to 200 mm. can be obtained. For a number of technical purposes, i.e., for checking of snap gages, inside and other calipers, or of slots, or in marking, these measuring discs are extremely useful. They are not intended as measuring rods and cannot be applied as such because of their shape and short length. Very recently, however, they have also been manufactured in larger lengths.

Fig. 9. Section through an up-to-date high-grade measure.

The end measures have only one measuring length, they are therefore used to advantage only where it must be determined whether a certain length, i.e., the distance between two surfaces, width or height of material, is as specified. Their range of application is for this reason the great province of

the gages. If it is necessary to measure distances, line-measures should be used. They can be considered as being composed of as many end measures as they contain divisions, and in this their special advantage lies. Bessel, who was especially inclined to end measures, raises the objection to line-measures that the definition of the measure by the distance of the limiting faces of the rod has the advantage, as against the definition by the distance of two points on its surface, because the former is changed in value by bending as the square, while the latter is subject to a change in the order of a product of the bending and the distance of the points from the axis of the rod. This is true, but measures with a division on or in the surface are used only in the case where the bending can be neglected with reference to the required low accuracy of the measurement, or if the rod is supported in such a manner that the deflection is very nearly overcome. In high-class measuring rods the line representing the length is placed, for both end measures and line measures, in the neutral plane of the measuring body.

Various methods have been tried to fulfill this requirement. Kater cuts the metal down on both ends of the measuring body to the axis of the rod (Fig. 8) and in this way obtains faces lying in the neutral plane on which the end-lines can be engraved. Sub-divisions can not be put on these measures. Troughton and Simms, in 1845, also retained the full measuring body when making the prototype of the yard, they only drilled a cylindrical hole to the axis of the rod at the two places where they wanted to place the end-lines of the measure. The lines are engraved on the bottom of this hole (see description, page 344). This solution can not be considered a very satisfactory one from the point of view of illumination. It is decidedly better to cut out the whole measuring rod down to the center plane and thus to lay bare the neutral plane for the whole length. This method has the further advantage that the measuring body becomes lighter and the rod easier to handle without impairing rigidity. Its application has led to 2 principal forms of section, the X-shape and the so-called trough-shape. The X-shape was proposed by Tresca and was applied in the prototype of the meter (Fig. 2). It was especially imperative due to the cost and density of the material. The trough-shape (Fig. 9) has been used for 2 measuring rods of the Physikalische Technische Reichsanstalt, one of which was made in 1878 by J. A. Repsold's Sons, Hamburg, the other in 1888 by C. Reichel, Berlin. Measures of this kind are theoretically without objection and also permit engraving divisions over the whole length. Industry and commerce, however, prefer a division on the surface of measuring body which, although not satisfactory where the highest accuracy is desired, still is more advantageous for common use because the length to be measured can usually be determined by placing the rod up to, or on, the piece to be measured. Depending on their purpose these measures have quadrangular, square, rectangular, diamond, or round (circular or elliptical) sections. On rods with diamond shaped section (with bevelled edges), the division is as a rule on the side-surfaces.

Measuring tapes, measuring wires and tape lines form a special type as the disadvantages with regard to accuracy of the measurements due to deflection are not counteracted by a special shape of section but by a tension determined by experience. Tapes and measuring wires are used in lengths up to 300 feet especially in geodetic surveying and have proved to be very satisfactory.

Bessel has the further objection to line-measures that the lines are seen differently under magnification by different observers. This objection, just as that first mentioned, holds good only for the most precise measures and is of no importance for measures in daily use

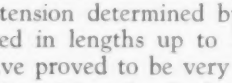

Fig. 10. Bomb shaped weight.

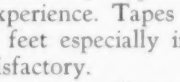

Fig. 11. Bell shaped weight.

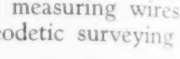

Fig. 12. Weight with button.

because of their lower accuracy. Bessel could have added that the lines are seen differently even by the same observer at different observations. The reason is that the line is nothing physical, has no body, but is simply an interruption of the surface, a hole, or a groove. As a line is seen the line of the deepest shadow which changes its position apparently or actually according to the condition of the eyes of the different observers, further for the same observer according to the condition of his eyes at the time he is making his observations, i.e., depending on the degree of fatigue or state of his nerves, and finally, independently of the observer, according to the brightness, nature, and location of the light source. This change is the greater the wider and deeper the line is, and the more the upper edges are rounded off. An attempt was made to overcome this drawback by filling in the groove with a black mass, which then appears as a dark line on the surface of the lighter body of the measure. Goepel[7] first copper-plated a scale of nickel-steel, then polished off the copper from the highly polished body so that it remained only in the grooves of the lines, and finally etched the copper black. This gives very neat black lines on a light background. A very interesting suggestion was made by Pensky. He draws very fine threads of a cob-web over a metal frame which he covers with a frosted glass plate. If this plate is illuminated from below

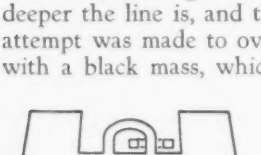

Fig. 13. Hexagonal weight with ring.

[7]Goepel: Erfahrungen dei der Herstellung einer Nickelstahl-Skala. Deutsche Mechaniker-Zeitung 1898.

the lines appear black on the yellowish-white background. A change of position of the source of light in the case has no influence. More recently, harder metals are used for the finest scales, the lines are not very deeply engraved and are made of smallest possible width. In this way, the prototypes of the meter have a line-width of only 6 to 8μ, but this was later reduced to 2μ width so that little leeway is left for a different conception of the lines and their location. Usually the lines are arranged so that they are intersected at right angles by 2 longitudinal lines a very short distance apart. The adjustment is then made on those places of the cross-lines lying between the longitudinal lines whereby the length of the measure is clearly defined. In this regard, the line-measures are absolutely equivalent to the end measures but they surpass them, as regards invariability. In all places where measureing-pins (contacts) must be used, even with the greatest care damaging the contact faces can hardly be entirely avoided; almost all end measures therefore show small indentations on the end-faces. With line-measures, comparisons are made with magnifying glass or microscope, reading telescope so that an injury to the lines is almost excluded as they are not touched. Where the highest accuracy is required the metrological science for some time has preferred the line-measures to the end measures and has particularly favored their perfection. Only recently has greater attention been paid to the end measures. Since industry has demanded that machine parts be interchangeable, a precision machine construction has been developed in which a hundredth of a millimeter is of importance. If, therefore, precision gages must be within 0.01 mm. the gages used for checking the former must have still greater accuracy. The measures required to keep the gages continually accurate are, therefore, not permitted to deviate from their nominal value by more than a few thousandths of a millimeter. That the art is capable of satisfying these strict requirements, especially for gage blocks is a clear proof of its high state of perfection.

(b) Form of Units of Mass and Volume. The most suitable shape for weights (units of mass) is that which has the least surface because it offers the smallest surface to wear; this would be a sphere. In former times, stone spheres with handles were often used as weights but generally only for beam-scales with unequal arms on which they were suspended. They cannot be placed on scale pans as, for this purpose, a segment opposite the handle had to be cut off the sphere to enable them to stand. This so-called bomb-shape (Fig. 10) is still used for weights in Russia. It was in use in Germany until the year 1884 for weights up to 50 kg. in order not to have to carry these heavy pieces from place to place but to roll them. Besides the bomb-shape, the bell-shape with a ring attached was much used formerly. (Fig. 11.) Both forms have the disadvantage that the handles can easily be broken off. To avoid this drawback the weights were then made with a button (Fig. 12). The body of the weight has the shape of a cylinder with circular section tapering upwards to a smaller neck which again broadens to a thicker head or button. Weights of this type are easily handled, stand firmly, and assure sufficient protection against wear in use. Neck and button are omitted only in weights of extreme accuracy

because all contractions permit the collection of dirt. Such weights must be handled with forceps, the jaws of which are lined with soft leather or velvet. The British prototype of the pound has been provided with a circular groove for the forceps. This arrangement must be considered as faulty for the above mentioned reason.

In the prototypes, the height of the cylinder is equal to its diameter. For the less accurate weights a higher shape is preferred for the simple practical reason that more of the narrower weights can be placed in the same space. Weights for commercial use from 200 grams downward, have broad shapes — diameter greater than height — because pieces with too small a base fall over easily. In some countries (Austria, Hungary, France, etc.) the commercial iron weights are made in the shape of a truncated hexagonal pyramid with a collapsible handle for lifting (Fig. 13). This was formerly also used in western Germany because these weights can be placed one upon the other which cannot be done with weights having the button. However, these weights wear very fast as the edges are knocked off. Weights under 1 gram are made as thin discs; in Germany for better distinction the pieces of the 5 series (500, 50, 5 mg.) hexagonal, the 2-series (200, 20, 2 mg.) square, and the 1-series (100, 10, 1 mg.) triangular with one bent-up corner. For analytical balances, bent wires (riders) are used as additional or sensitivity weights for placing on the beam which, in this case, is generally provided with divisions.

Measures of volume (dry measures) are usually given the shape of a straight cylinder with circular section. In liquid measures, the height is generally much greater than the diameter as with increasing narrowness of the vessel the accuracy of the measurement increases with regard to the permissible limit of error in commercial measures—the errors of adjustment become smaller. In liquid measures, flush measures and line-measures are distinguished according to whether the level of the liquid is indicated by the upper edge of the container or by a line placed on the measure, generally around it. In the last case the measuring body tapers upward having a bottle-shape.

Conditions are reversed for dry measures. Number and dimension of the interstices become the smaller, and the setting of the material more uniform and denser, the wider the container is. These dry-measures are therefore given the shape of a flat cylinder with larger diameter than height. Large measures sometimes have a box shape.

Measurement of Air Flow

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CHAPTER IV.

THE FLOW OF AIR IN PIPES.

Before considering practical methods of measuring the flow of air along a pipe, it will be useful, in order to define more closely the requirements which must be fulfilled, to discuss in some detail the nature of the flow. This subject appears to have been first studied from a general standpoint by Osborne Reynolds, whose classical researches * showed that two distinct types of flow are possible. Reynolds investigated the motion of water in straight horizontal glass tubes by means of a small quantity of colouring liquid introduced from a jet at a point on the axis near the inlet end. At low speeds of flow the colouring liquid was drawn out into a filament extending along the axis of the tube. As the speed was gradually increased the filament remained perfectly well defined until, when a certain speed was reached, it began to depart from linearity some distance from the mouth of the tube, and to show evidence of the formation of eddies in the water. When the speed was further increased the region of commencement of eddy formation approached nearer to the inlet of the tube, until finally the thread of colour completely lost its individuality and became diffused throughout the body of the water, in which turbulent motion had now become general. With a given size of tube and the water at a constant temperature, the speed at which eddy motion commenced was more or less constant ; but if the experiment was reversed, that is to say, the speed was gradually reduced from an initial value at which the motion was turbulent, the eddies were found to die out at a speed which was much more definite and somewhat lower than that at which eddy motion commenced for ascending

* *Phil. Trans. Roy. Soc.*, 1883.

Editor's Note: INSTRUMENTS has secured the American publication rights of "The Measurement of Air Flow" by E. Ower. This treatise will be published serially in INSTRUMENTS, the first installment appeared in the October, 1929 issue. The complete treatise can be obtained from the INSTRUMENTS' Book Shelf.

speeds. The colour method could, of course, not be used for this reversed experiment; the transition from turbulent to steady motion was detected in this case by observing the change in the relation between velocity and resistance * to flow in the pipe which occurs when the type of flow changes.

The speed at which steady flow changes to the turbulent variety is termed the higher critical velocity, and that at which the reverse effect takes place as the speed is reduced, the lower critical velocity. Since, as we have seen, the latter is the more definite, it is usually called simply the critical velocity, and this practice will be followed here.

We see, then, that in dealing with the flow of water in pipes (and it will be shown immediately that this applies also to the flow of air), we have two possible types of motion to consider. In the first the flow is of the stream-line character, the speed is slow and the inertia forces are small compared with the viscous or tangential frictional forces existing between neighbouring elements of the fluid. It appears, therefore, that for this type of motion viscosity is predominant in determining the nature of the flow, and it is, in fact, found that calculations of such motions, based purely on theoretical reasoning, agree accurately with experimental observations, the accord being so good that methods based on the slow stream-line flow of liquids through narrow tubes have been adopted for absolute determinations of viscosity. The other possible type of motion is turbulent; in this case the speed is higher and, in consequence, inertia forces can no longer be neglected.

It is necessary now to consider which type of flow occurs most commonly in engineering practice. For this purpose we shall require a definition of the coefficient of viscosity of a fluid. Let us take the case of a viscous fluid moving past a plane surface, the flow being everywhere parallel to the surface. The action of viscosity, or the tangential frictional forces between adjacent layers of the fluid, will be such as to tend to retard the faster moving layers and to accelerate those travelling more slowly. It follows that the fluid nearer the surface will move more slowly than that further away; it appears probable also that a very thin layer of fluid in immediate contact with the surface will be at rest, and actual observation confirms this deduction. A tangential force will therefore be exerted on the boundary, and a velocity gradient will exist in a direction normal to the surface. If v is the velocity parallel to the surface at any distance y measured perpendicular to the surface (Fig. 14), the velocity gradient at the surface (or the rate at which the velocity increases as the distance from the surface

increases) is given by $\frac{dv}{dy}$ * measured at the surface, and if F is the total tangential force acting on an area S of the surface, the coefficient of viscosity (usually denoted by μ) of the fluid is defined as being such that

$$F = \mu S\left(\frac{dv}{dy}\right)_{\text{surface.}}$$

In general, we may, instead of considering the tangential force on the solid boundary, replace the latter by the surface of

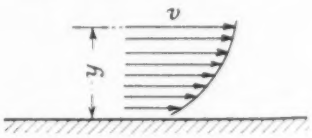


FIG. 14.

separation between any two contiguous layers of the fluid itself, and write

$$F = \mu S\frac{dv}{dy},$$

where $\frac{dv}{dy}$ is now the velocity gradient at the fluid surface in question.

From this we see that μ may be defined as " the tangential force on unit area of either of two horizontal planes of indefinite extent at unit distance apart, one of which is fixed, while the other moves horizontally with unit velocity, the space between being filled with the viscous substance." This definition is due to Maxwell.

We are now in a position to consider in greater detail the results of Reynolds' investigations. From experiments conducted in pipes of different diameters with water, for which the value of μ was altered by varying the temperature between 5° C. and 22° C., he deduced the fact, which is of fundamental importance, that the critical speed v_c occurs at a constant value of the ratio $\frac{v_c d\rho}{\mu}$, where d is the diameter of the pipe, and ρ is the density (mass per unit volume) of the water. He found also that this formula was applicable to other fluids besides water, and his and subsequent investigations have definitely established its general validity for the motion of all fluids along pipes.

Experiments to determine the magnitude of the constant

* If the velocity is proportional to the distance from the surface the gradient is, of course, simply $\frac{v}{y}$.

value of $\frac{v_c d\rho}{\mu}$ at which the transition from turbulent to stream-line flow occurs agree in indicating an average figure of 2000 * for parallel pipes of ordinary smoothness, so that for any fluid

$$v_c \dagger = 2000 \frac{\mu}{d\rho}.$$

If we take the case of air at 15° C., $\frac{\mu}{\rho}$ is equal to about 0·00016 in foot-pound-second units (it should be remembered that ρ is the weight per unit volume—in this case per cubic foot—divided by g, the gravitional constant) so that the critical velocity in feet per second is given by $\frac{0{\cdot}32}{d}$, where d is in feet. If, for example, we consider a one-foot diameter pipe, the critical velocity for air at 15° C. occurs at 0·32 feet per second; alternatively, for air at 15° C. the critical velocity does not reach one foot per second until the pipe is about $3\frac{5}{8}$ inches in diameter.

It will be realised, therefore, that the stream-line flow of air in pipes is exceptional in practice, and that in the great majority of cases the flow will be turbulent. We shall therefore consider this type of flow more closely, and defer until the end of this chapter a short discussion of stream-line flow, which it has been thought advisable to include for the sake of completeness.

The Resistance of a Pipe to the Motion of a Fluid along it.—Let us consider first a mass m of fluid moving along a horizontal pipe at a speed v, which is uniform across the section of the pipe, and subjected to a pressure (static pressure) p. Also let ρ, as before, denote the mass of unit volume of the fluid. The kinetic energy of the fluid is given by $\frac{1}{2}mv^2$ and the potential energy, i.e. the work necessary to bring the mass of fluid from a region of zero pressure to a region where the pressure is p, is $\frac{mp}{\rho}$, so that the total energy (referred to the mean level of the pipe) is given by

$$m\left(\frac{v^2}{2}+\frac{p}{\rho}\right), \qquad \text{i.e. by} \qquad V\left(\frac{\rho v^2}{2}+p\right),$$

* The reader with a knowledge of dimensional theory will see that the quantity $\frac{v_c d\rho}{\mu}$ is non-dimensional, so that the value of the constant (2000) is applicable to any set of units.

† Throughout this chapter, unless otherwise stated, the velocity v in a pipe is to be taken as the mean velocity, i.e. the volume of fluid passing in unit time divided by the cross-sectional area of the pipe.

since $m = \rho V$, where V is the volume of the mass m of the fluid. Hence the energy per unit volume of the fluid is

$$\tfrac{1}{2}\rho v^2 + p.$$

It will be noted that each of the two terms in this expression has the dimensions of a pressure, and that their sum is, in fact, the total pressure of the fluid which would be measured by the facing tube of a Pitot and static tube. If there were no resistance to the motion of the fluid along the pipe, and no loss of energy due to the formation and dissipation of eddies, this total pressure would remain constant. Actually, of course, such dissipation of energy does occur, and there is also a resistance due to the viscous forces acting at the walls of the pipe, which causes a further loss of energy. If we consider two sections, one at each end of a straight length of pipe, we see that there will be a loss of energy as unit volume of the fluid passes from the upstream to the downstream section; a corresponding amount of work will consequently have to be done in forcing this unit volume along the pipe. The resistance of the length of pipe between the two sections may therefore be taken as equal to this quantity of work. Further, since, as we have seen, the energy per unit volume passing a section is equal to the total head at that section, the resistance of the length of pipe will manifest itself by causing the total head at the downstream section to be less than that at the upstream section.

It is thus apparent that the resistance offered by a length of pipe to the passage of a volume of fluid along it may be measured in terms of the drop in total head experienced by the fluid in passing along this length, and in practice this method of expressing the resistance is universally adopted.

So far we have considered only flow in a parallel-walled straight pipe in which the velocities at all points in a cross-section are the same, so that the mean total head at that section can be obtained from a single measurement at any point in its plane. We shall see shortly, however, that such flow rarely, if ever, occurs in practice. Experiments show that the velocities are not in general the same at all radii in a given section of a parallel pipe along which a fluid is moving steadily.* It is found that the velocity is usually a maximum at the axis of the pipe and falls away towards the walls, and there seem to be definite indications that there is a very thin layer of the

* Steadily is here used in the sense that the motion is unaffected by external influences such as the effect of the inlet to the pipe, or fluctuations in the speed of the fan or other actuator producing the motion. It is not to be taken as implying non-turbulent motion.

† Neglecting small effects such as the slight thickening of the retarded boundary layer of the fluid in contact with the walls, which occurs as the motion proceeds down the pipe.

fluid in contact with the walls actually at rest. We must consider therefore how to measure resistance in an actual case, i.e. how to determine the mean total head across a section where the velocity is not uniform.

Before discussing the general case we may consider a straight parallel pipe, which presents no difficulties. In the first place, if the flow is parallel to the walls the static pressure across any cross-section must be constant. If this were not so the air would tend to flow from the high pressure regions to those of low pressure, and the resultant motion would not be parallel to the walls. Secondly, once the flow has settled down to the normal distribution in a straight pipe (see above), that is, at a sufficient distance from the inlet, we may state that the distribution of velocity at all sections is the same.† Now the mean total head at any section will be equal to the static pressure p at that section, which, being uniform, may be obtained by a single measurement anywhere in the section, together with the velocity head corresponding to the mean kinetic energy of unit volume of the air passing the section. If we denote the velocity corresponding to this mean kinetic energy by $\bar{v}$, the velocity head is $\frac{1}{2}\rho\bar{v}^2$.

Consider now a length of pipe whose end sections are denoted by A and B. The mean total head at A will be greater than the mean total head at B by a pressure R_p which is equal to the work done on unit volume of the fluid in moving from A to B, i.e. to the resistance of the length AB of the pipe. We therefore have the equation,

$$\tfrac{1}{2}\rho\bar{v}_A^2 + p_A = \tfrac{1}{2}\rho\bar{v}_B^2 + p_B + R_p. \quad . \quad . \quad . \quad (1)$$

Now since, as already stated, the velocity distribution at all sections is the same for the assumed conditions, $\bar{v}_A = \bar{v}_B$, so that (1) becomes

$$R_p = p_A - p_B. \quad . \quad . \quad . \quad . \quad (2)$$

The physical significance of this equation is that, for steady flow in a length of straight pipe, the resistance is measured by the difference between the static pressures at the two ends of the length in question. It should be noted that ρ at the two sections has been assumed to be the same, an assumption which is strictly true in the case of an incompressible fluid such as water, and sufficiently accurate for most purposes for such fluids as air, provided the pressure difference $p_A - p_B$ is small compared with either p_A or p_B. Fortunately this condition is usually fulfilled in practical cases of air flow, so that equations (1) and (2) may be used as they stand.

Still confining ourselves to the case of the parallel pipe, we may consider the matter from another point of view. Suppose F is the frictional force resisting the motion, per unit

area of the internal surface of the pipe, whose diameter is d. Then the total resistance of a length l of the pipe is equal to

$$F\pi dl.$$

This frictional force tends to arrest the motion of the fluid along the pipe, and, for the flow to proceed steadily, there must be an equal force acting on the fluid in the pipe along the direction of motion. The latter force will be provided by the pressure difference between the two ends of the length l of the pipe. Calling the pressures at the ends p_A and p_B as before, we see that the force on the volume of fluid contained at any instant by the length AB of the pipe (Fig. 15) will be given by

$$(p_A - p_B)\frac{\pi d^2}{4},$$

acting along the direction of motion. Hence

$$F\pi dl = (p_A - p_B)\frac{\pi d^2}{4},$$

or

$$p_A - p_B = \frac{4Fl}{d}. \quad . \quad . \quad . \quad . \quad (3)$$

The case of a pipe of varying cross-section is more complicated and, since the matter which follows immediately is concerned with parallel pipes, consideration thereof has been deferred to the end of this chapter, in order not to interrupt the argument.

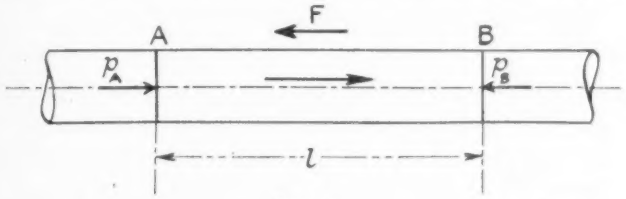


FIG. 15.

The Characteristics of the Flow in Pipes.—An extensive investigation of the flow of fluids along smooth straight pipes of drawn brass has been carried out by Dr. T. E. Stanton and the late Mr. J. R. Pannell,* the experiments being intended to establish values of F for different fluids flowing at various speeds in pipes of different diameters. The fluids used were air, water, and thick oil, whilst the pipes ranged from 0·12 inch to 5·0 inches in diameter and the speeds from 1 to 170 feet per second. The resistance F per unit surface area of each pipe for each condition of flow was determined by measuring the pressure drop over a given length of pipe, which was situated

* *Phil. Trans. Roy. Soc.*, A., 1914, vol. 214, p. 199.

sufficiently far from the inlet to ensure that disturbances due to entry had died away before the working portion was reached. The results are of the greatest interest and practical importance. It was found that when the values of $\frac{F}{\rho v^2}$ were plotted against $\frac{vd}{\nu}$ †, all the observations, irrespective of the fluid used, the diameter of the pipe, or the mean speed of flow, fell on a single curve; in no case was the departure from the mean curve greater than could be accounted for by the limit of the experimental accuracy. The curve consisted of two parts (see Fig. 16), of which one—the left-hand portion—corresponded to values of $\frac{vd}{\nu}$ below about 2000, i.e. where the flow was of a stream-line character, and the other to values of $\frac{vd}{\nu}$ above this, for which the flow was turbulent. The two branches of the curve were connected by a region of instability, corresponding roughly to values of $\frac{vd}{\nu}$ of 2000 to 3000, which marked the transition from one type of flow to another.

Turbulent Flow in Pipes.—As we have already seen, turbulent flow is the type with which engineers are almost invariably concerned, so that the portion of the curve for values of $\frac{vd}{\nu}$ in excess of about 3000 is that which is of immediate interest. Dr. C. H. Lees,* from an examination of the data given by Stanton and Pannell, together with those of other investigators, has proposed the following formula for the resistance per unit area :—

$$F = \rho v^2 \left\{ 0{\cdot}0009 + 0{\cdot}0763 \left(\frac{\nu}{vd} \right)^{0{\cdot}35} \right\}, \quad . \quad (4)$$

whence, by the use of equation (3), we obtain

$$p_A - p_B = \frac{\rho v^2 l}{d} \left\{ 0{\cdot}0036 + 0{\cdot}305 \left(\frac{\nu}{vd} \right)^{0{\cdot}35} \right\}, \quad . \quad (5)$$

where p_A and p_B are respectively the pressures at the ends A and B of the length l of the pipe.

The curve deduced from equation (4) coincides accurately with the mean curve through the points obtained by Stanton and Pannell, and the portion of Fig. 16 pertaining to turbulent flow has been calculated in this way.

† The symbol ν is extensively used to represent the ratio $\frac{\mu}{\rho}$, which is called the " kinematic viscosity " of the fluid.

* *Proc. Roy. Soc.*, A., 1915, vol. 91, p. 46.

Equation (5) is of practical importance since it enables the resistance of smooth parallel pipes to be calculated for any condition of flow. It should be noted that the resistance, or pressure drop per unit length, does not vary as the square of the speed, since, if this were the case, the quantity

$$\left\{0{\cdot}0036 + 0{\cdot}305\left(\frac{\nu}{vd}\right)^{0{\cdot}35}\right\}$$

would then have a constant value, and the curve in Fig. 16 would be a straight line parallel to the axis of $\frac{vd}{\nu}$. It will be noted, however, that the curve, although not parallel to this axis, tends to become so as the value of $\frac{vd}{\nu}$ increases, so that the error involved by assuming that the frictional resistance varies as the square of the speed becomes less at the higher values of $\frac{vd}{\nu}$. The highest value of $\frac{vd}{\nu}$ shown on the curve is about 400,000, which corresponds to a velocity of about 65 feet per second for air at 15° C. in a one-foot diameter pipe. In practice

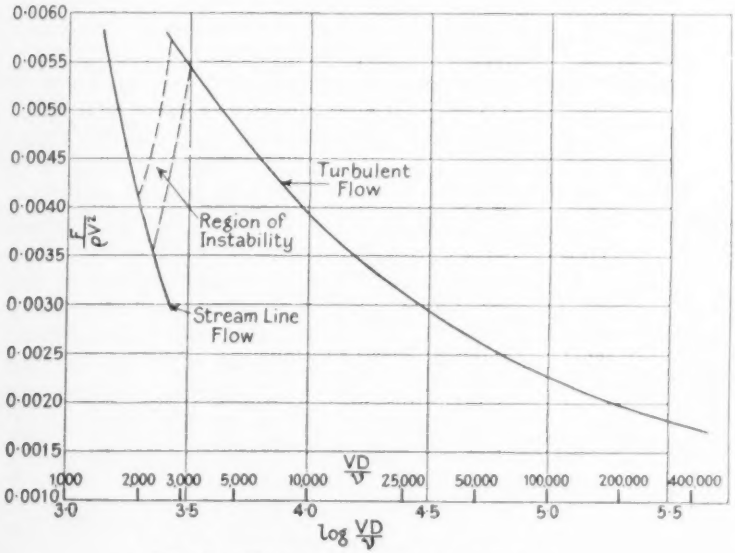


FIG. 16.—Resistance of smooth circular pipes.

it is often convenient to assume that F varies as some power n of v, and Lees * has deduced the following empirical expression for the index n, which fits Stanton and Pannell's results with

* *Loc. cit.*

good accuracy :—

$$n = 2 - \frac{29{\cdot}7}{\left[85 + \left(\frac{vd}{\nu}\right)^{0{\cdot}35}\right]} \quad . \quad . \quad . \quad . \quad (6)$$

For smooth parallel pipes we may therefore assume that $F = kv^n$ and calculate n by the use of (6). For $\frac{vd}{\nu} = 3000$, where the region of turbulent flow may be regarded for practical purposes as commencing, n will be found to be 1·71, and for $\frac{vd}{\nu} = 400{,}000$ it becomes 1·83. These values are strictly applicable only to smooth-walled pipes: the question of rough pipes is more complicated, as the degree of roughness affects the results to a material extent. It is found that as the roughness increases n approaches the value 2, in which case $\frac{F}{\rho v^2}$ will have a constant value, which appears to be somewhat higher than the corresponding value for smooth pipes. For the pipes ordinarily used in practice, provided they are reasonably smooth, the curve of Fig. 16 and the values of n obtained from equation (6) will usually be found to provide a sufficiently good basis for estimating the frictional resistance.

Velocity Distribution Across a Section.—The form of the curve of velocity distribution for a smooth pipe as obtained by Stanton is shown in Fig. 17. Stanton found that up to a radius equal to 0·8R, where R is the internal radius of the pipe, the distribution curve for a smooth pipe is parabolic, so that the velocity v_r at a radius r (where r is less than 0·8R) is given by

$$v_r = v_a - Ar^2,$$

where v_a is the velocity at the axis and A is a constant.*

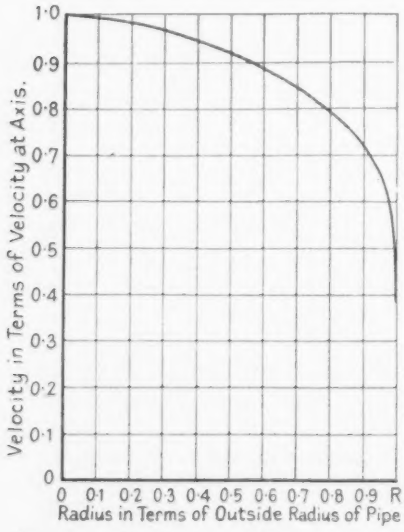


FIG. 17.—Distribution of velocity across smooth circular pipes.

In Stanton and Pannell's research on wall friction, to which reference has been made above, it was, in many instances, found

* *Proc. Roy. Soc.*, 1911, A., vol. 85, p. 366.

convenient to deduce the mean velocity from a single reading of the velocity v_a at the axis measured by means of a Pitot tube, the static pressure being obtained from a hole in the side of the pipe.* For this purpose it was necessary to determine accurately the relation between v † and v_a for all conditions of flow, and a comprehensive investigation of this relationship was undertaken as a preliminary to the major research on wall friction. Although the results obtained were thus subsidiary to the main experiments, they furnish data which is at least of equal value to the engineer, since they enable him to obtain the mean speed of flow in a long parallel pipe from a single reading of velocity taken at the axis.* Fig. 18 exhibits the results in graphical form. When the values of $\frac{v}{v_a}$ were plotted against $\frac{vd}{\nu}$ it was found that all the points fell on the mean curve reproduced in Fig. 18, irrespective of the fluid

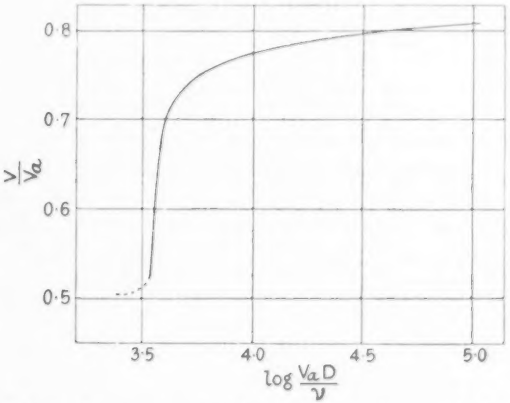


FIG. 18.—Relation between mean and axial velocity in smooth circular pipes.

(air or water) or the diameter of the pipe. For values of $\frac{vd}{\nu}$ below the critical, the ratio was found to be 0·5, which, as we shall see shortly, is the theoretical value for viscous streamline flow. At the highest value of $\frac{vd}{\nu}$ obtainable the value of the ratio was 0·81. This curve can be employed with confidence to give a good approximation to the mean speed from a measurement of v_a, provided that the section at which the

* See Chapter VIII.

measurement is made is, as was actually the case in the experiments under consideration, at a considerable distance from the inlet to the pipe, so that disturbances originating there may have had time to die out. Stanton and Pannell took their observations at distances varying from 90 to 140 diameters from the inlet, since previous experiments had shown that disturbances may persist for a considerable distance along the pipe. In practice the section should be at least some 40 or 50 diameters from the inlet. Although this restriction constitutes a serious objection which may often preclude the use of this method for determining the mean velocity of flow, cases will frequently occur in practice where the necessary conditions are fulfilled, and the method may be adopted.

In the case of rough pipes, where the frictional resistance varies as the square of the speed, Stanton found * that the velocity distribution was parabolic up to a radius very nearly equal to the inner radius of the pipe, and that this distribution did not, as it did in the case of the smooth pipes, vary with the value of $\frac{vd}{\nu}$. The ratio $\frac{v}{v_a}$ for these rough pipes had the value of about 0·76. It should be noted that the pipes in question were artificially roughened, by cutting double screw threads on the internal surfaces, in order that the frictional resistance should vary as the square of the speed—a point that was verified experimentally. It will be realised, therefore, that the pipes were appreciably rougher than those commonly employed in practice, and it would thus appear that, subject to the restriction previously specified, the curve of Fig. 18 relates sufficiently closely to ordinary conditions to justify its practical application.

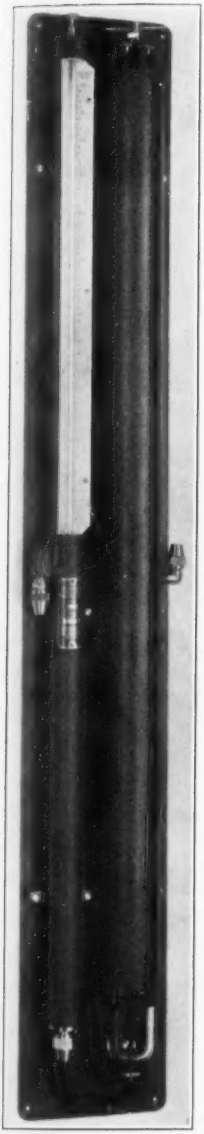
NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional information

New Fuel Flow Indicator

(Commercial Engineering Laboratories)



THE new Research fuel flow indicator embodies the same general principles used in this instrument since it was introduced more than five years ago, but contains improvements which seem desirable based on the experience of the users of these instruments during this period.

Fuels of all kinds invariably contain foreign matter which is objectionable in the present day laboratory. It accumulates in the strainers and jets of carburetors which are being tested and eventually causes trouble. The new Research indicator is equipped with a new centrifugal edge filter which provides a large separator consisting of a cylindrical tank to which the fuel enters through specially designed jets. After the fuel is cleaned in this manner it passes through a Cuno edge filter which consists of a large number of thin plates assembled with spacers. These thin plates are effective in taking out foreign matter which will readily pass through the ordinary filter. The very important feature of this filter is that it can be cleaned by a few turns of the handle without draining the fuel system or stopping the flow.

The accuracy of the new Research fuel flow indicator is greater than has heretofore been obtained in any instrument of this type. It is possible to obtain this degree of accuracy by a special form of metering head and metering tube which were developed after many months of research. All Research indicators are calibrated individually and repeated readings on the new instruments check each other within a small fraction of one percent.

The new instruments are also finished in a new crystalline lacquer which is very durable and which gives the instrument a very pleasing appearance.

New Moll Recording Microphotometer

(P. J. Kipp & Zonen)

Type A. The microphotometer is intended for the investigation of photographed spectra. The spectrogram is fixed on a plate holder. A beam of light from an incandescent lamp passes through the plate on its way to a vacuum thermocouple (or a divided thermopile) connected to a coil galvanometer and the deflections of the galvanometer are photographically recorded on a sheet of bromide paper stretched on a drum.

By moving the plateholder slowly and at the same time rotating the drum, a record is made showing all the details of the spectrum under examination.

The microphotometer is constructed in two types. Type A is suitable for all kinds of accurate work. It resolves the finest details of the negative and assures a high accuracy in measuring line distances. Moreover, it is extremely rapid, allowing the recording of a spectrum with hundreds of lines in a few minutes.

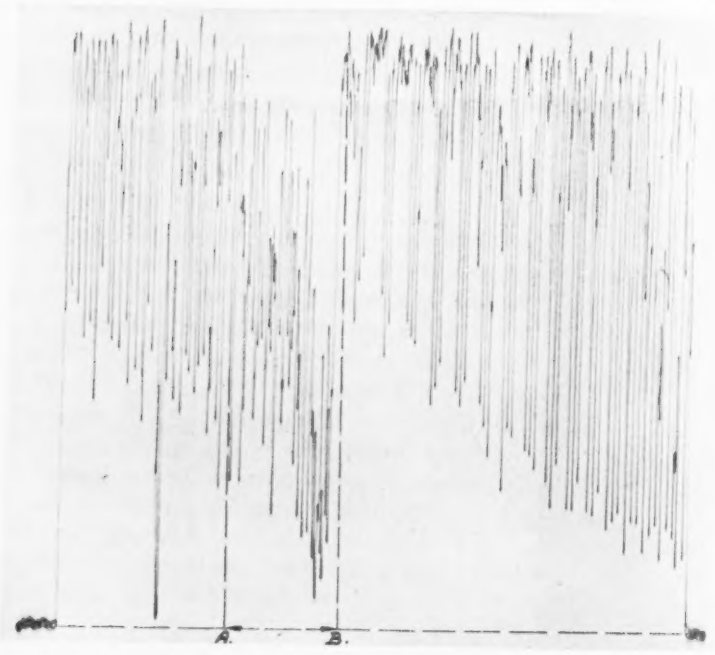


Fig. 1. Part of band spectrum of nitrogen recorded in less than 10 minutes with the type A microphotometer, the ratio being 1:7. (5/6 reduction.)

The principle of the apparatus will be clear from Fig. 2. Condensor C projects an image of the filament of a small incandescent lamp upon slit S_2, O_2 and O_1 are objectives, the former throwing a greatly reduced image of slit S_2 on the negative N, and the latter forming an enlarged image of the illuminated part of the negative on slit S_1. Objective O_3 concentrates the light transmitted by S_1 onto the vacuum thermocouple V. The drum camera D forms part of the apparatus, while the galvanometer G is set up at some distance away.

Fig. 3 shows the whole apparatus, except the galvanometer and electric motor. The lantern, slits, the two objectives on either side of the plate holder and the holder of the thermocouple are visible in front.

The lamp is connected to a 6-8 volt storage battery of at least 80 amp. hours capacity; a small rheostat and a voltmeter built in the heavy base plate of the apparatus control the voltage at the terminals of the lamp.

The vacuum thermocouple designed especially for the microphotometer is extremely rapid, equilibrium of temperature being reached within about two tenths of a second. It is to be used with the new Moll microgalvanometer having the same short time of indication. The rapidity of the new microphotometer A is about ten times that of the original Moll type described in the Proc. Phys. Soc. of London, Vol. XXXIII, Part IV, June 15, 1921. This improvement has been attained without any sacrifice in the sensitivity, the latter being even still greater than before.

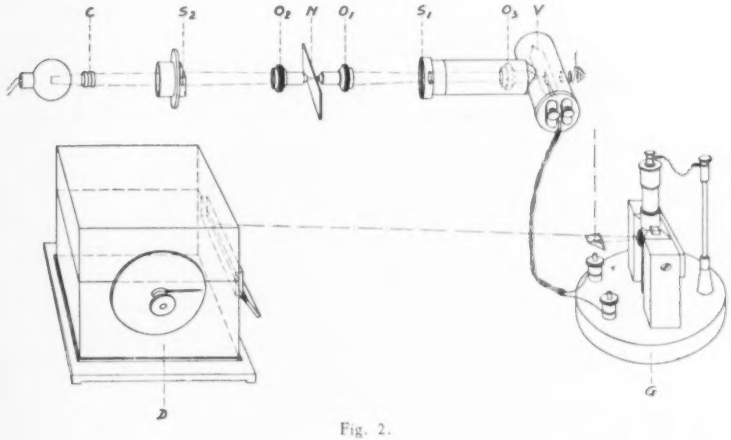


Fig. 2.

The plateholder, mounted on a slide, is displaced by means of a micrometer screw. The maximum displacement is 6 cm. but a further 6 cm. of the plate can be recorded by simply shifting the plateholder back by hand. This movability of the plateholder has another advantage. If only two or three parts of the negative are of interest to the operator, those parts alone may be recorded adjustable over a height of 5 cm., so that several spectra on one negative may be recorded successively. Finally it can be turned about the optical axis, by which means the position of the negative may be adjusted so that the light beam consecutively passes through similar parts of the various spectral lines (i.e. at the same level on the plate).

The drum is rotated by means of the same shaft which carries the micrometer screw displacing the negative. For this purpose two different gears are mounted on this shaft. If the drum is connected to one gear, 1 mm displacement of the plate corresponds to 50 mm of the drum periphery. The other gear gives a ratio of 1:7. The sheet of bromide paper on the drum measures 12x40 cm, thus 40 cm correspond either to 0.8 or to 5.8 cm of the photographic plate.

Both the worm gears and the micrometer screw are of the highest precision. An accuracy of the screw within one thousandth of a mm is guaranteed. The proportionality of the displacements of negative and drum can be verified by means of a contact disc which can be mounted on the main shaft. This disc has 10 exactly equidistant contacts which make a lamp (placed near the galvanometer) flash up every time the shaft has made one tenth of a revolution. These flashes give a system of parallel lines on the paper, corresponding to displacements of the plate over one tenth of a mm.

If very narrow spectra, i.e. star spectra, are to be recorded, the objective O_2 should be replaced by a microscope condenser, while the objective O_1 may be substituted for one of larger aperture.

For investigations of slight line displacements the thermocouple in mounting may be replaced by a Moll divided thermopile containing two series of 8 thermocouples, each series being in contact with a pair of terminals fitted on the ebonite back of the mounting. These two pairs of terminals are connected to two separate Moll galvanometers, both galvanometers recording on the same drum. In this way two records can be made simultaneously, the one of the spectrum to be investigated and the other of the comparison spectrum. Displacements of a line of one micron can be ascertained.

For working with the divided thermopile, the ordinary Moll galvanometers are used. The Moll microgalvanometer mentioned above cannot be used in connection with this thermopile, but only in connection with the vacuum thermocouple.

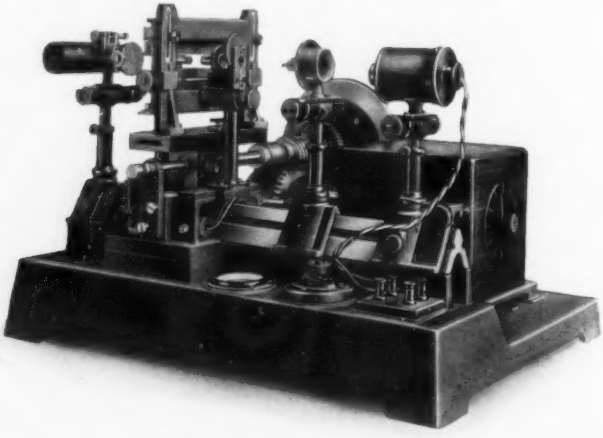


Fig. 3. Type A Microphotometer.

For spectra photographed on long films the plateholder can be provided with a device for unrolling the film. A 1/30 H.P. electric motor connected to a reducing gear forms the driving mechanism. The current for this motor is automatically switched off as soon as the record has been made. It is not necessary to work with the apparatus in absolute darkness. A fairly strong lamp may be kept lit in the room as long as its light does not point directly at the camera slit.

Type B. In cases when the utmost precision is not required, i.e. for the investigation of continuous spectra and spectra with broad lines, such as X-ray spectra, the type B microphotometer may advantageously be used. Though built on the same principle as the type A, it is much simpler.

On one side of the plateholder the lantern with an objective is placed, the latter forming a reduced image of the filament directly on the negative. On the other side of the plateholder another objective and a Moll thermopile are mounted together on one stand. A sharp image of the illuminated part of the photographic plate is projected on the thermopile slit.

The plateholder is mounted on a slide moved by means of a steel wire which is given the necessary tension by means of a spring. The displacement of plateholder and drum is effected by a clockwork connected to the drum shaft, the speed of which is adjustable between 15 minutes and 9½ hours per revolution of the drum by means of a magnetic brake.

One revolution of the drum corresponds to 15 cm displacement of the plateholder (ratio 1:2⅔). A 7.5 cm displacement of the negative (ratio 1:5⅓) can be obtained by using a smaller disc.

Instruments for Production Testing Work

*P. MacGahan**

THE manufacture of electrical apparatus and in fact manufacturing processes in general carried out on a production basis often involve the necessity for accurate measurements of the electrical quantities involved.

An example of this is the manufacture of radio vacuum tubes of different kinds. The accuracy required for such measurements is in general much higher than that obtainable with ordinary panel or switchboard type instruments. For example it is well known that a slight error in the setting of the grid voltage in the testing of radio tubes will result in a very large difference in the plate current. Therefore if sufficiently close test limits are set on plate currents to assure in this respect a satisfactory tube characteristic many good tubes will be rejected in testing and many defective tubes will be accepted due to lack of sufficient instrument accuracy. Similarly a higher order of accuracy is needed for many of the other production measurements in many manufacturing processes aside from radio tubes.

Switchboard instruments are not primarily intended for close measurement work. Their principal field of application is for operating or con-

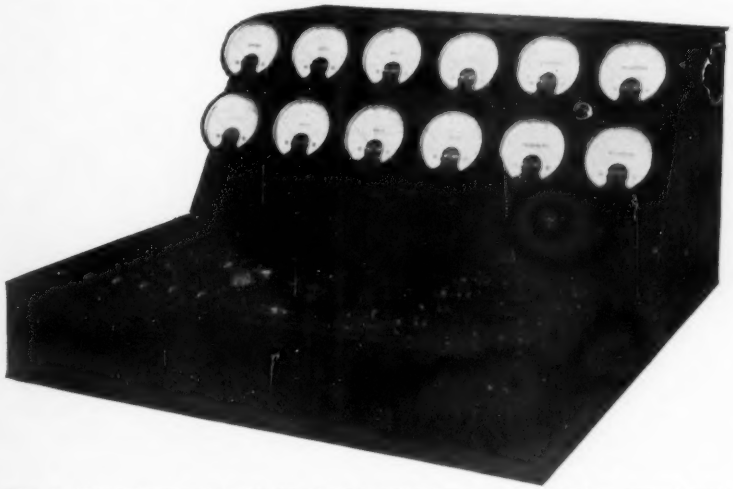


Fig. 1. Westinghouse radio tube test bench showing instruments mounted on vertical panel at the rear of the bench.

trol. The pointers are furnished with large index ends to facilitate reading at a distance and for the same reasons the division lines are made very heavy. The calibration accuracy of switchboard instruments is generally of the order of 1 to 3% allowable error. Many of the smaller

*Meter Engineering Department, Westinghouse Electric & Manufacturing Co.

types of switchboard instruments are furnished with etched printed dials resulting in variable accuracy at different scale points.

The accuracy considered essential and acceptable for switchboard instruments can be obtained without exceptional care in balancing the movement. The design of the bearings, pointers, and other parts are intended to withstand the overloads and rough usage of operating or control work rather than carrying the delicacy required for high accuracy work.

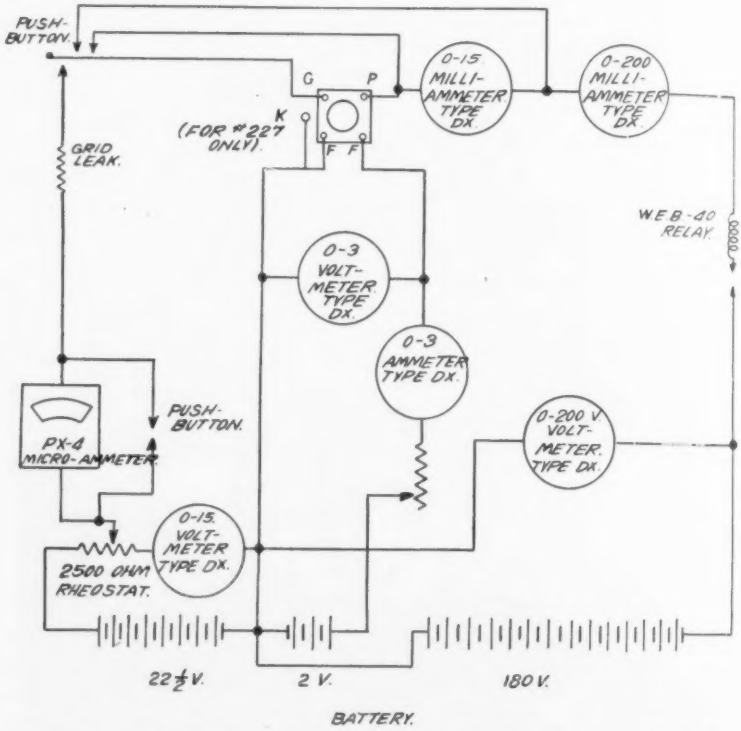


Fig. 2. Typical test bench circuit connections for testing 1½ volt a-c. amplifier tubes. For other tubes use batteries and meters of suitable capacity.

Portable instruments, however, are designed for use where greater accuracy is required. The preferable position for the use of portable instruments is horizontal and this involves practical difficulties in their application to permanent testing benches designed for speedy production testing such as in radio tubes or similar modern manufacture. It is generally the practice to mount the test sockets on the top surface of the test bench together with the switches and other controls and mount the test instruments on vertical panels at the rear of the bench in a position easily read by the operator making a self-contained outfit. This enables quick readings to be taken.

Figure 1 shows a bench of this character. Typical circuit connections are shown in Figure 2 as intended for testing 1½ volt amplifier tubes.

With large production it is desirable to specialize the test positions or benches for testing of each piece of apparatus only, therefore simplifying the connections and controls and avoiding multi-range scales on the instruments. This means that in any manufacturing plant there will be many different test outfits as there are different varieties of apparatus to be tested.

Unfortunately in the past there has been as indicated above, a conflict between such test requirements and the use of switchboard type instruments which do not have sufficient accuracy for test purposes.

In order to provide a line of instruments especially intended for this class of service instrument engineers have carefully studied the problems of testing measurements in production for large quantity production work as regards to measuring instruments and this has resulted in the design of the so-called "panel standard instruments." These were originally intended for mass production work on vacuum tubes but are of course equally applicable to all kinds of manufacture where quick high accuracy inspection readings or tests are necessary.

Briefly the "panel standard instruments" consist of the combination of a panel or switchboard type cases and mountings into which are placed high-accuracy portable instrument mechanisms. The dial markings are hand calibrated of the fine line type enabling close readings to be taken and the calibration is performed with the same painstaking care and by the same experts that perform the calibration on the high grade portable instruments.

Therefore these instruments possess so far as possible the accuracy and qualifications of the corresponding portable types. The reservation "as far as possible" in the above statement is introduced because due to the horizontal position of the pivot in the bearings of panel mounted instruments there must of necessity be somewhat more pivot friction than in the bearings of portable instruments which are normally vertical in position. This is due to the fact that with a vertical shaft arrangement the contact between the pivot and the jewel is at the center line of the pivot,

Fig. 3. New Westinghouse panel standard d-c. voltmeter.

Fig. 4 New Westinghouse panel standard milliammeter, three quarters view.

and therefore the friction works at a much shorter radius than in the case of the horizontal shaft. In horizontal shafts the end play requirement is such that the contact point between the pivot and the jewel is at the side of the pivot and therefore at a point where the effective radius is greater. Consequently, there is more friction effect.

Figures 3 and 4 clearly show the scales and pointers in two of these panel standard instruments. The scales are almost 4" long and very clearly divided. The cases however are only 4⅜" in diameter and therefore the instruments are very compact indeed taking up the least possible space on the panel. The cases are made of heavy, soft-drawn steel, which shields the movement from external magnetic fields. A large amount of experience particularly in actual production of radio tubes has shown that this size of instrument is the best suited for general production testing purposes.

The scales are long enough to make accurate readings on the lower parts which is often necessary and yet the pointers are not too long which would cause instability or variations in balancing due to moisture or other causes.

The happy combination of portable instrument movements and scales with switchboard cases and mountings is thought to be entirely novel and should find a large application in all kinds of testing work where the otherwise preferable horizontal position of portable instruments cannot be employed.

The general designation of "panel standard instruments" has been chosen as being both descriptive of this new type distinguishing it from "portable standard instruments" and also from the usual switchboard or panel instruments.

———— :: ————

"Gyrorector"

(Pyrometer Instrument Company)

THE method of operation of the "Gyrorector" differs from gyroscopic instruments serving a similar purpose known heretofore as the gyroscope does not in this case stabilize its system, as usually done, by its own gyroscopic pressure, but has the object of controlling a relay, which operates in the sense of the actual gyroscopic precession forces. By such means the inventor has succeeded in obtaining with a comparatively very small gyroscope, effects, which heretofore, even when using very heavy and big fly-wheel-bodies, had been thought impossible.

The special working method of the gyroscopic system corresponds with the special use made in the "Gyrorector" of the gyroscopic movements. One advantage of the instrument, which must not be underrated, is the aperiodic swinging in. Whereas all gyro-pendulums, made heretofore, consist of systems oscillating periodically, which means that they re-adjust themselves to equilibrium by oscillating to and fro, the special quality of the "Gyrorector" is to glide slowly back into the position of equilibrium without passing beyond. It is by such means only that it has been possible to avoid all wrong indications, which some-

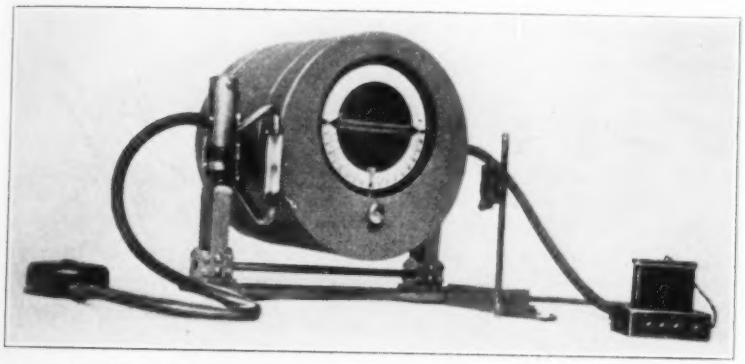
times may become very considerable and arise particularly in consequence of resonance of oscillations.

The "Gyrorector" provides indications in respect to all three dimensions.

1. It indicates the transverse inclinations of the airplane.
2. It indicates the longitudinal inclinations of the airplane.
3. It makes known even the smallest deviations from the straight course with great accuracy.

The condition under 1 is accomplished by the property of the "Gyrorector" to act as vertical indicator, or, what is identical, as an artificial horizon.

The indicative part of the vertical indicator is designed as a vertically arranged dial with index, on which the horizontal and vertical lines are specially marked. By comparing the position adopted by the arrow mark of the casing, the index provides means to read off at any time the exact degree which the airplane in any inclined position deviates from the horizontal plane. The arrow-mark and the casing are subject to all transverse inclinations, and therefore, alter their position according to the corresponding inclination of the airplane, whereas the dial and the horizontal line marked thereon, always maintain the same position. Dial and indicator, therefore, form the inalterable center, round which the arrow-mark and the gyrorector-casing turn within the airplane, and therefore, are the indicating device.



Longitudinal inclinations of the airplane are satisfactorily indicated by a water-level attached to the case on its side.

In order to also obtain an exact indication of curves, a pendulum is opposed to the vertical indicator which is thoroughly independent in its movements from the dial, and oscillates in the plane of the dial which is the transverse plane of the airplane. The curve indication of the "Gyrorector" is obtained by the combined effect occurring at each deviation from the straight course, and, therefore, also in each curve, that the vertical indicator, consisting of dial with vertical indications, is retained in its vertical position, and on the other hand, the pendulum assumes a position corresponding to the resultant force of gravity and centrifugal force. Consequently an angle between those two direction indicators must necessarily indicate a curved flight, whereas coincidence

of both indicates a straight course. It may be added that the magnitude of the angle of differences always corresponds with a certain angle-speed of the curved flight.

Another advantage offered by the pendulum is that it indicates in curved flights the properly inclined position of the airplane, due to the fact that the pendulum in any improper position of the airplane will deviate in the direction of banking. As already explained, the pendulum follows all lateral inclinations of the airplane, and consequently will in improper positions at first remain at the zero mark of the case, since the effect of improper lateral position in respect to the pendulum is at once suspended by a lateral acceleration of fall or banking. Such imaginative acceleration in its original degree could, however, only continue for a very short period as very soon it will experience a delay by the lateral air resistance. Although such delay, as experience has taught, is not noticed by the occupants of the airplane for some time, it is of sufficient importance to influence the pendulum, and to force it to deviate somewhat in the direction of banking or shifting. One has consequently to count with a little delay in the indication of the correct curve flight. At any rate it may be maintained that improper positions of lateral inclinations will be indicated by the pendulum quite distinctly within two to three seconds after their origination. In other words, this means that the pendulum, due to its quality to act upon dynamic occurrences much quicker than the human nerve-system, is very suitable to give useful service to the aviator in respect to proper navigation in curve flights.

With the "Gyrorector" as a safe operating artificial horizon the aviator never risks slipping or falling when at night, in fog, clouds or inclement weather he no longer feels the position of his airplane in relation to the earth. The "Gyrorector" makes it possible at any time to see at a glance, whether and by how many degrees the airplane has a lateral inclination, whether the curves are taken correctly or incorrectly, or whether the risk of slipping occurs by banking too much. Consequently the "Gyrorector" offers the greatest possible safety by giving evidence on the following three direction moments:

1. Lateral inclination (angle of the transverse axis of the airplane to the horizontal),
2. Longitudinal inclination (angle of longitudinal axis of the airplane to the horizontal),
3. Curve (direction and degree of horizontally taken curve).

Since by actually straight flying the needle of the magnetic compass may be kept quiet, and then may be used as a reliable indicator of direction, the "Gyrorector" provides at night, in fog and bad weather:

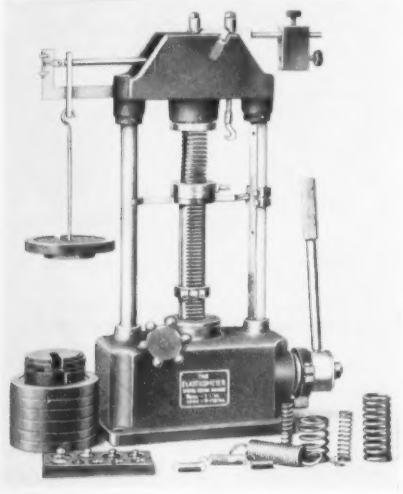
4. The direction of the compass (angle of horizontal projection of longitudinal axis of airplane to the meridian).

It may be noticed that all four indications are referred to the horizontal. Owing to the high number of cycles of the three phase current, disturbances by the magnetic field of the gyroscope of "Gyrorector" are avoided, and any magnetic compass may be placed next to it. The instrument may be erected at any place of the airplane without danger of interfering with its indications.

Elasticometer Spring Testing Machines for Tension and Compression Tests

(Coats Machine Tool Co., Inc.)

IT is a matter of common knowledge that springs to the same general specifications give widely varying results, in actual practice. These differences are due to a variety of conditions governing spring manufacture which cannot be brought under absolute control. Not only spring manufacturers but also users of springs, for this reason, have felt the ever increasing need of a method by which unskilled labor may examine a large range of springs dependably and on a production basis.



The new Elasticometer Spring Testing Machines entirely fulfill these requirements and will be found invaluable wherever dependance must be placed upon uniform operation of various forms of mechanism, tightly closing valves, etc.

The knife-edge operated weighing mechanism is located in the upper housing and has a ratio of 1:10. The main improvements which these weight-operated types show over previous designs are the great reduction in the number of knife edges employed. Knife-edges and links form an integral part of the two main levers. They are made in one piece of special steel, hardened and ground complete on the machine. This is in contrast to the former practice of securing knife-edges and links in separately made levers. Only the main knife axis is mounted in the Elasticometer when the machine leaves the works. The remaining parts of the weighing mechanism are packed in a box and wrapped separately. They are easily assembled in a few minutes on hand of an assembly drawing packed with each machine. It is practically impossible to assemble these parts incorrectly. This arrangement not only prevents damage in transit but also makes for easy accessibility, permitting periodic inspection and cleaning of the weighing mechanism.

The load is determined by placing loose weights on the weight beam. Variations in length are read in 1/32″ on the scale attached to the right pillar in such a way that the actual length of the spring in either its open, compressed or elongated state is indicated. This is a distinct improvement over the previous type which indicated, not the actual

length of the spring under test, but the number of inches the spring had been compressed or stretched, making it necessary to subtract from or add this amount to the open length of the spring. Adjustable stops for limiting both compression and tension stroke are provided for quantity inspection. In addition, there are movable tolerance markers both on the balance scale and on the vertical length scale.

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Zernike Thermopile

(*P. J. Kipp & Zonen*)

This new thermopile consists of eight elements of improved bismuth alloys giving an e.m.f. of 120 microvolts per degree centigrade. The usual disadvantages of such elements, namely high resistance and slow response, are compensated here by making the wires extremely short. The elements are entirely covered by a copper receiver 2 microns thick and 2 mm in diameter. The thermopile is hermetically enclosed in a copper capsule of 1 cm diameter which is covered by a plate of quartz so that the instrument may also be used for measurements in the ultra violet. By building this capsule into a mounting in a very special way, all temperature influences from outside were completely compensated and so the characteristic feature of this thermopile could be attained, namely its great insensitivity to outside disturbances. The instrument is "shielded" and one can touch the mounting with a warm hand without causing any deflection in a sensitive galvanometer. It has, therefore, a great zero stability.

The mounting of the thermopile has a diameter of 23.2 mm and fits into any normal microscope tube (replacing the eyepiece). In this way, for example, the Zernike thermopile is used in the Schilt photometer for the photometry of photographed star images.

A lens system of 25 mm focus in holder can be screwed on the mounting, by which a radiation falling on a surface of 20 mm diameter can be concentrated on the receiving surface of the thermopile. When using this lens system the mounting must of course be directed exactly, as it should project the aperture of a microscope or telescope objective, or the source of radiation, on the receiving surface.

The mounting fits in a tube (see illustration) provided with a bi-lateral slit of 18 mm height, which can be opened to 3 mm. The stand of this tube can be placed on any normal triangular optical bench.

Resistance of thermopile = 20 ohms. The position of equilibrium is attained within 3 seconds after radiation falls on the pile.

Electromotive forces in microvolts generated in the pile when placed at 1 metre distance from the source of light:

	Candle	4 Volt 25 C.P. gas-filled lamp	Quartz mercury-arc 300 Watt	Quartz mercury-arc, 300 Watt, through monochromator f/11		
				λ 10140	λ 5461	λ 3655
Uncovered	5	—	—	—	—	—
With quartz plate	2	3	15	—	—	—
With lens system	110	160	600	—	—	—
Through slit 18 x 1 mm	8	12	45	27	44	35

New Direct Current Instrument of Ultra Sensitivity

TO meet the requirements for ultra sensitive miniature direct current instruments, the Jewell Electrical Instrument Company has developed in their Pattern No. 88 Instruments, ranges as low as 200 microamperes, full scale.

These instruments are contained in the flush type moulded black bakelite case of the size which is rapidly becoming standard for miniature instruments, namely, having a case diameter of 2¾ inches and a flange diameter of 3⅜ inches. The bakelite cases are correctly cured, the material being completely polymerized—the result is a most excellent completely insulated case.

Pattern 88, with these new ultra sensitive ranges, are provided with multiple layer coils and high quality bronze springs adjusted to full scale deflection of 200, 300, and 500 microamperes, respectively, for ranges carried in stock.

These microammeters will prove to be of considerable value in research work, and may be used as deflection galvanometers in bridge circuits, plate microammeters in vacuum tube voltmeters, and work of a similar sort. In conjunction with proper resistors they may be converted into voltmeters with a full scale value as high as 5000 ohms per volt.

Despite the fact that these ultra sensitive instruments are extremely difficult to manufacture, due to the economies of quantity production, the cost has been kept down and the instruments are available at very reasonable prices.

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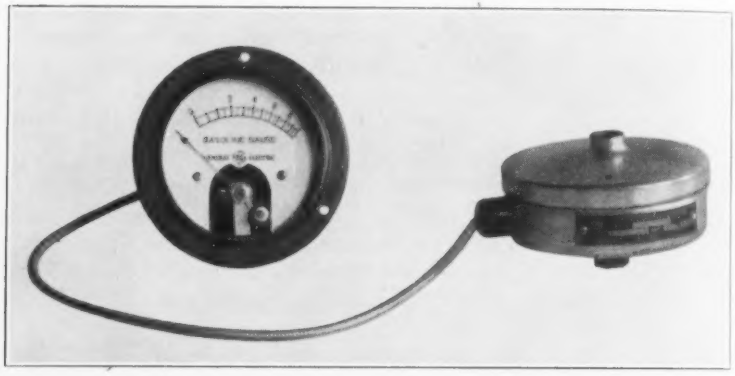
New Airplane Gasoline Gauge

(General Electric Company)

THIS new gasoline gauge for aircraft is electrically operated and gives accurate readings under practically every condition of normal flight. It depends for its operation on the hydrostatic head of the gasoline to be measured and has no moving parts whatever except the needle of the indicating instrument and the switch.

The new gauge was designed to meet the requirements of reliability, accuracy, light weight and simplicity of installation. Essentially it is an electrically operated, remote indicating, pressure balance, the electric energy being supplied by the storage battery, dry-cell battery or electric generator with which the aircraft is equipped. A complete installation consists of one or more pressure balance units, a remote indicating instrument (actually a milli-ammeter calibrated in gallons) having as many scales as there are separate tanks to be measured, and a normally open hand-operated tumbler switch for each pressure balance. Every tank to be measured independently of the remainder of the gasoline supply requires a separate pressure balance, but where it is merely necessary to measure the total contents of a multi-tank ship, one pressure balance alone will serve the purpose.

An important part of each installation is the normally-open tumbler switch. This device insures a dead circuit at all times except when the pilot wishes to read his gasoline supply, thereby preventing unnecessary consumption of electric energy and overcoming any chance of fire from broken wiring in the event of a crash.



The standard method of installing the pressure balances is to thread them into reinforcing plates welded to the under sides of the tanks. If, however, one-unit systems are used in multi-tank ships, the single pressure balance is usually located at some point near the union of the various feeder pipe lines. The indicating instrument and each tumbler switch are conveniently mounted on the pilot's instrument panel, and to complete the circuit it is only necessary to run a length of armored twin conductor wiring between pressure balances, tumbler switches, the indicating instrument and the electric supply.

Each pressure balance weighs approximately two pounds net, a single indicating instrument weighs 5½ ounces, a tumbler switch weighs one ounce and the twin conductor wiring weighs about 0.32 ounces per foot. Thus an ordinary one-unit installation weighs less than three pounds complete.

Lucky Altitude Temperature Correction Computer

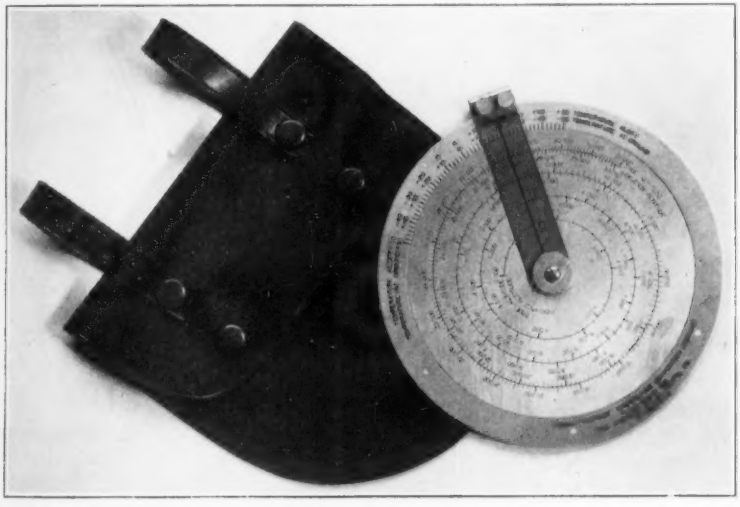
(American Paulin System, Inc.)

THE Altitude Temperature Correction Computer is a simple instrument which provides the aerial photographer with a convenient means for making corrections for errors in the altimeter indication which are due to variation in the temperature of the air column. These errors are negligible for most flying work, but accuracy is essential to the aerial photographer who desires to obtain absolutely consistent results on days when the temperature varies greatly.

This instrument is in the form of a simple, disc computer. In addition to a good altimeter (whose calibration is known to be accurate and according to the latest standards) the only additional instrument necessary is a strut thermometer, graduated in degrees centigrade.

The altimeter, of course, will usually be already installed in the airplane. The thermometer should be mounted outside the cabin and exposed to the slipstream where it will not be affected by heat from the engine, and the computer may be carried in the leather case which is supplied with it. Straps are attached so that it may be easily hung alongside the photographer.

The instrument is used as follows: Before take-off note the temperature of the air on the ground and set both celluloid arms together so that the inner edges coincide with the existing ground temperature on the "Temperature at Ground" scale. Lock both arms by tightening the thumb screws.



Next take the airplane off and climb until the altimeter indicates approximately the elevation at which it is desired to fly. The plane is flown level for a few moments while the proper correction is deter-

mined as follows: Rotate the inner dial of the computer until, on the "Indicated Altitude Scale," the elevation given by the altimeter coincides with the inner edges of the two arms. Next obtain the free air temperature from the strut thermometer. Without disturbing the other, one of the arms can be moved so that its inner edge coincides with the free air temperature on the "Temperature Aloft" scale. This adjustment is made and the arm locked. The inner edge of this arm will then intersect the "True Altitude" scale at the correct elevation at which the airplane is now flying. The airplane is then climbed or dived as found necessary to change the indicated elevation by a sufficient amount to correct the error. If the error was large, it will be well to recheck again at the new indicated altitude.

As an example: Suppose that the temperature at the ground is plus 20° centigrade. Both arms are set to this value and locked. Suppose now that the airplane is climbed to an indicated altitude of 12,000 feet. The inner scale is then rotated until 12,000 feet on the "Indicated Altitude" scale coincides with the inner edges of the arms. Suppose that the temperature of the air is now 0° centigrade. The right arm is unlocked and moved to the right to zero. The true elevation of the craft is then obtained from the intersection of the inner edge of the right arm with the "True Altitude" scale. In this instance it is 12,340 feet. Thus, in order to fly at a true elevation of 12,000 feet the airplane must descend 340 feet, or to an elevation of (12,000—340=11,660) 11,600 feet, as indicated by the altimeter.

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OB Detachable Watthour Meter

(Westinghouse Electric & Mfg. Co.)

THE OB detachable watthour meter consists of the standard temperature-compensated OB watthour meter housed in a weather-proof case and has these unique advantages:

Plug terminals which make installation or removal easy; detachable meters can be plugged into place or removed in a moment like radio tubes.

Suitable for mounting in any location, outdoor or indoor.

Reduces labor, reading, and testing costs.

Completely iron-clad and tamper-proof.

Adjustable terminal block which permits mounting the meter with conduit entrance at top, bottom right or left.

Particularly adaptable to modern methods of conduit wiring employed in apartment buildings.

This meter fills a long-felt want for a watthour meter that can be mounted either indoor or outdoor and that can be installed or removed quickly and easily.

Light Intensity Meter*

*James L. McCoy***

THIS meter is self contained and carried as a complete unit in one case. The light sensitive pick-up is a photoelectric cell covered with a shield. A window is cut in one side to admit the light to be measured. The photo electric cell unit is connected to the meter by a six foot double conductor cord making it possible to move the cell unit around within that radius without moving the case. The instrument contains a commercial portable micro-ammeter calibrated directly in foot candles. The smallest size "B" batteries are wired and mounted into the case. As very little energy is required, the battery life will be about its shelf life.

The photo electric cell is generally known as a light sensitive tube having somewhat the appearance of a radio tube. The tube has two distinct parts, an anode and cathode. The cathode is coated light sensitive material giving the tube its characteristics. Many other commercial uses have been found for the photo cell. It is used as a smoke detector, to sound an alarm in case of fire, to count the product of quantity production as the cars are counted as they pass through the Holland Tunnel, by the interrupted beam of light. The cell plays an important role in several different schemes of motion picture sound reproduction. (The resistance of the cell will vary with intensity of the light striking it.) There are a number of different types of cells and their characteristics vary materially with the elements used. They can be made of different materials to respond to different wave lengths of light. Dr. Rentschler of our Research Department has constructed a photo electric cell that will respond only to ultra violet region of the spectrum. This cell is now being used in an ultra violet recording device, making it possible to obtain a quantitive reading in ultra violet units.

The cell used in our light intensity meter is a special cell having a very broad response, covering the visible spectrum. This response is such that it will fit in very well for light measurements where the combination of Mazda light and panchromatic film is used. A spectroscopic study of the response of the panchromatic film when plotted against the light of the Mazda lamp shows that the results are somewhat near

*Abstract from a paper presented before the Society of Motion Picture Engineers in Toronto, Canada, on October 10, 1929.

**Westinghouse Lamp Company.

a straight line making it possible for the meter to give an integration that will come close to the photographic results obtained with given light values. The use of this meter is suggested to be of considerable value when colored pictures are taken because of the integration of the values of different wave lengths of light through the visible spectrum. The same cell can also be used for the measurement of north sky daylight giving approximately the same values for the same intensity from a photographic standpoint. The photo cell as used is directional in its pickup making it possible to study the light from different angles. The pickup can be made non-directional if so desired.

The sensitivity is such that a range of full scale readings can be made from 100 foot candles to 3000 foot candles. We believe the range of 400 to 500 foot candles, as read on a full scale of 1000 foot candles will fit the studio requirements the best, but this is a matter to be controlled by the professional studio man.

In order to provide a simple and effective means of calibrating the meter, without returning it to the factory, we plan to mount a low voltage lamp in the meter case to check the cell for calibration. At a definite spacing a calibration check can be easily made. The lamp will be a six volt type to be supplied with energy from a six volt external battery.

Mr. M. W. Palmer of the Paramount-Famous-Lasky Corp., has been doing some work with this photometer during the past few months, to determine the light values on motion picture sets. He has informed me that while he was checking the light reflected from an actor's face, the light intensity meter picked up the change in illumination caused by this man lighting a cigarette. This incident may illustrate how sensitive this device is to change in light intensity.

We believe this device has an application in connection with the film printing machines. There are a number of different settings of the printing lamp required to have the film printed without glaring or too dark results. To control this condition, the different settings must be made by the operator. In order to try the light intensity meter for this application, a special mask for the photo cell has been made to fit into the aperature of the printer. Mr. La Grand of the Paramount-Famous-Lasky Corporation has been making tests to determine the meter's value in this field. The meter has also been suggested as a means to analyze the light on a motion picture screen.

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Electrically Operated Scale for Determining Moisture Content of Lumber in the Dry Kiln

(Fairbanks Morse Company)

HALF-WAY between a modern sawmill and its shipping department is the heart of the lumberman's business. The success or non-success of his business often depends on the efficiency of his dry kilns.

No inspector, however expert, is able to grade quality into lumber that has been abused in its seasoning.

Temperature, circulation, and humidity have been brought well within control and the dry-kiln operator is in a position to conclude with reasonable accuracy the condition of his operation so far as these factors are concerned.

He charges the kiln, closes the doors, and is to a great extent compelled to trust to luck as to what is to happen to a kiln full of clears for the next 48 hours or so. The only method he has for getting an inkling as to what is going on inside the kiln is to open the kiln doors several times during the course of the charge, thus periodically upsetting all the temperature, circulation and humidity conditions he has carefully built up.

T. E. Heppenstall of Longview, Washington, became interested in improved kiln drying practices. Working on the established fact that change of weight from time to time, as the season progresses, is indicative of the moisture content of the stock, he set to work to design a machine to weigh lumber in the kilns while seasoning. The scale which he developed has been subjected to test after test for over two years and has been brought to such a state of perfection that it is now a reliable piece of dry kiln equipment.

This is an electrical device which indicates the moisture content of lumber as it dries in the kiln. It has been tested thoroughly and has been developed into an astonishingly simple instrument. Its design is scientifically correct and it has a high degree of accuracy.

The system of determining moisture content is by means of weight which at present is the only known accurate method and the standard for all methods. The scale is located on the roof of each dry kiln and a rod extends down into the kiln; one or more representative boards are suspended from this rod by means of hooks.

The regular method of predetermining the moisture content of representative boards from the kiln is used, small sections being cut off, weighed, dried and re-weighed. Representative board or boards, which should weigh about 60 lb. are then suspended from the scale by means of chains and a hooked rod attached to the scale lever mechanism. The poise on the scale beam is then set at a point where the reading equals 100 per cent plus the predetermined percentage of moisture. Adjustment is made by a hand knob until the scale beam is balanced, and then the poise is set back to 100 per cent. The scale box is then closed and locked, and the scale need not be disturbed until another charge is put in the kiln.

The scale transmits its reading electrically to any convenient point such as an office or control room where a motor shows the moisture content in per cent of kiln dry weight.

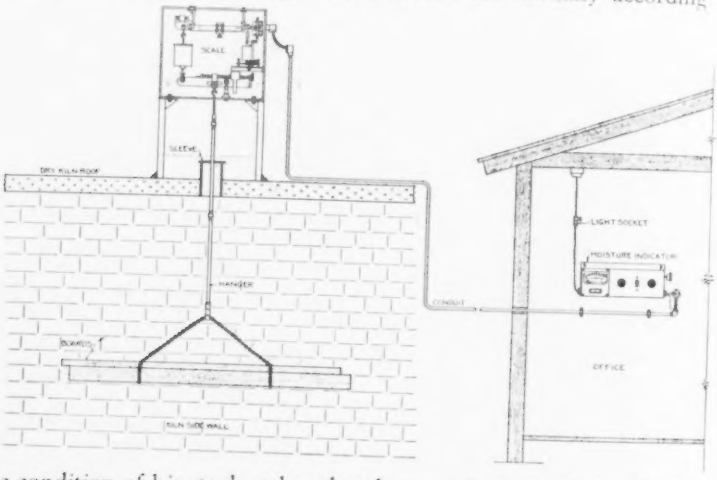
The kiln operator at his office can tell at a glance the actual condition of the lumber in any of the dry kilns. The meter indicates the moisture content without the necessity of making a calculation. The condition of the lumber can be watched every minute or hour of the day if necessary without any further attention by the operator. Any number of kilns can be thus equipped, but only one meter is required

at the office. This meter can be connected to any dry kiln simply by inserting a plug in a small switchboard, which is connected with the scale of each kiln.

The accompanying drawing shows the general arrangement of kiln, scale and meter. It also shows the location of the representative boards. It is a relatively simple matter to locate these boards or place baffles so that they are subject to average conditions of temperature and circulation in the dry kiln.

The results made by the indicating instrument may be plotted graphically on paper with the temperature and relative humidity and the conditions of drying can be analyzed. A chart of this nature will show if there is a waste of time throughout the run, and make it possible to reduce the drying time.

This equipment makes possible the better seasoning of lumber because the condition of the lumber in the kiln is known definitely at all times. The final desired moisture content is assured. It will also speed up the drying of lumber in the kiln by eliminating the flat points in the drying curve. This means a large saving in operating expenses and also a small capital expenditure. It is responsible for a better grade of stock by decreasing the amount of checking and case hardening, etc., because the operator changes his schedule scientifically according to



the condition of his stock rather than by a predetermined time schedule.

Weather conditions and failure of steam or electric power are reflected in the quality of the lumber coming from the kiln because the time schedules are upset, but when the moisture content of the stock is known, the drying can be resumed at the proper temperature and humidity.

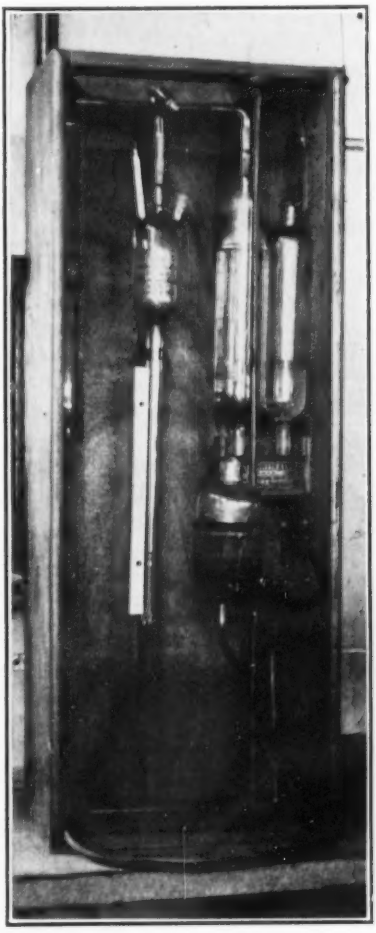
It eliminates the errors which creep into the old method of using short samples two or three feet long. End drying causes errors in short samples. This is partially overcome by painting the ends but this takes time and the paint costs money. Standard lengths are used in the moisture content indicator. Full length boards are used for samples. The saving by this feature is evident.

New Volumetric Carbon Determination Apparatus

(Birger Egeberg)

AN apparatus for the rapid volumetric determination of carbon in iron and steel has been developed.

The apparatus is made for use with a high temperature, carborundum resistance combustion furnace, and is exceedingly simple in construction and design. It consists of a cooling tower which brings the gaseous products of combustion to a constant value, a gas measuring burette to evaluate and record changes in volume, a gas washing vessel, and a capillary manifold to connect the various working parts one to another.



The cooling tower is made up of a coil of capillary glass tubing, water jacketed, and is located between the combustion furnace and gas measuring burette, and serves the purpose as mentioned above, of bringing the gaseous products of combustion issuing from the combustion furnace to a constant value.

The gas measuring burette consists of a double-walled, water jacketed, glass vessel, the lower portion of which is fitted with a movable scale graduated to read percentage of carbon direct. It is also fitted with a thermometer, and an automatic valve which regulates flow of gases, and is connected to a leveling bulb used in making readings. By use of this unit, changes in volume of gaseous contents before and after absorption of carbon dioxide are recorded.

The gas washing or absorption vessel is also double-walled and water jacketed, and is fitted with three automatic valves to govern flow of gases. It is also designed to split the flow of gas into several streams, thus insuring maximum scrubbing action. This unit serves the purpose of removing the carbon dioxide formed during the combustion of the steel from the measured volume of gas contained in the burette.

The manifold is a system of capillary leads, controlling the direction of gaseous flow during the analysis by means of hand-operated two and three-way stopcocks.

The general method of operation of the apparatus is relatively simple. The total amount of carbon in a steel sample in the form of small turnings is completely converted in a stream of oxygen at a temperature of 1000° C. into carbon dioxide. The combustion of the steel sample weighing one gram which has been previously weighed in a porcelain receptacle takes place in the electrical furnace, in which a porcelain combustion tube is placed for receiving this porcelain receptacle. The oxygen current passing through the tube forces the carbon dioxide originated by the combustion together with the remaining oxygen into a burette, in which the gases are collected up to a definite mark shown by the water which serves as a sealing liquid. The combustion gases are then led to an absorption tube containing caustic potash in solution by means of which the carbon dioxide is totally absorbed.

The gases are then returned to the burette, and the amount of carbon present in the sample is shown by the decrease of the volume and can be read in percentage direct.

The time required for a determination by use of this apparatus averages three and one-half minutes, a factor of greatest importance in analysis work. No technical knowledge is required in carrying out the tests, the cost per determination is very low, and accurate readings of carbon content are given to the second decimal.

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Engine Temperature Indicator For Aircraft

Type DO-18

(General Electric Company)

ENGINE-TEMPERATURE indicators of the thermometer type, as commonly used in aircraft, indicate lubricating-oil or cooling-water temperatures rather than the temperatures of the engines themselves. In the case of air-cooled engines, it is customary to locate thermometers in the lubricating-oil lines, or in water-cooled engines, in the cooling-water systems. Whereas both of these applications give indications of the general thermal condition of the engines, it is also important for long engine life and dependable operation to know at all times the rate at which engines are heating or cooling as well as the temperature of vital hot spots. This is especially true of air-cooled engines, where too rapid heating may be detrimental and where very fast cooling may occur without visual warning to the pilot—for instance, during a long glide in cold weather preparatory to landing. Under such conditions engines may become so cold as to fail to function if power is suddenly needed—without warning from the oil-temperature indicators.

The thermocouple engine-temperature indicator accurately measures the temperature of cylinder heads, cylinder walls, or any hot spots that may be of particular significance. It is instantaneous in operation and,

therefore, gives immediate indications of heating and cooling. A complete indicator consists of a thermocouple, twin-conductor leads, and a cold junction, temperature-compensated, remote-indicating instrument. Two different forms of thermocouples are optional with the purchaser. One is a straight threaded design arranged to be screwed into a quarter-inch tapped hole in the engine. The other is in the shape of a washer and can be mounted between the spark plug and cylinder head in the same manner as a gasket, making a very simple installation.

In the laboratory and test room, thermocouples have been used for this purpose for sometime, but they have been limited in aircraft applications by the necessity of the operator having to correct for varying air temperatures. This objection, however, has been overcome completely in the Type DO-18, as all corrections are automatically made by the instrument itself. The compensation is accomplished by the use of G-E metal No. 747.

This metal has a peculiar property whereby its magnetic permeability changes with changes in temperature. Placed in the magnetic circuit of the indicating instrument, it is affected by the same air temperatures as the leads and counteracts the errors which would otherwise be introduced.

No battery or electric energy supply of any kind is required, as the thermocouple generates its own electricity in proportion to the temperature to which it is heated. The thermocouple has no moving parts and nothing whatsoever to get out of order. The indicating instrument is made of the highest grade materials and represents the finest workmanship.

The Type DO-18 engine-temperature indicator is accurate to within 3 degrees Fahrenheit for ordinary air temperature changes. Where extreme variations are encountered, such as between sea level and high altitudes, the maximum error is not more than 10 degrees Fahrenheit. Since it is customary to calibrate the scales from 100 to 650 degrees Fahrenheit for air-cooled engines, the maximum error of 10 degrees is very small.

An indicator complete with thermocouple, 16-foot leads, and indicating instrument weighs 1 pound and 3 ounces net. They give instantaneous indications of:

1. Engine hot-spot temperatures.
2. Rate of heating and cooling—so that engines can be operated to give maximum life.
3. Dangerous overheating and cooling in flight.

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Prest-O-Weld Two-Stage Oxygen Regulator

(*Oxweld Acetylene Company*)

THIS regulator, which is designated the type R-109, incorporates the stem-type valves, which have proved extremely satisfactory in single-stage regulators. It is designed to eliminate fluctuation in working oxygen pressures.

The chief feature of the improved design is two-stage pressure reduction, accomplished through the medium of two independent sets of diaphragms, valves and springs. Instead of reducing the full cylinder pressure of about 2000 lb. per sq. in. down to working pressure, which is often only a few lb. per sq. in., in one-stage, the R-109 regulator reduces through this wide range in two stages. In the first stage the cylinder pressure is reduced through a non-adjustable reducing valve to about 175 lb. per sq. in. Leaving the first stage the oxygen passes to a second valve and diaphragm assembly, where the pressure is reduced to that desired by the operator, the second-stage reducing valve being adjustable by means of the hand wheel. Thus, instead of reducing the full cylinder pressure to working pressure, the second stage is required to regulate pressures within only a narrow range, which it can do easily and efficiently.

When the pressure in the cylinder falls below about 175 lb. per sq. in., the first-stage valve remains fully open. It is thus automatically cut out of the system and the second-stage valve and diaphragm only are operative. The type R-109 regulator will operate with equal efficiency whether the oxygen cylinder is full or nearly empty, and the working pressure will remain constant.

Trouble sometimes experienced in the past from opening cylinder valves with the adjusting screw of the oxygen-regulator turned in, thus permitting the full cylinder pressure to enter the low-pressure gauge and rupture the Bourdon tube or damage the valve stem of seat, has been largely eliminated in this regulator since it is impossible for the full cylinder pressure to enter the low-pressure gauge. The first-stage valve is of such sturdy design that it will withstand the most severe impact likely to occur.

The type R-109 oxygen regulator supersedes the type R-105. It is provided with 3000-lb. and 100-lb. gauges, and is equipped with a ¼-in. ferrul hose connection.

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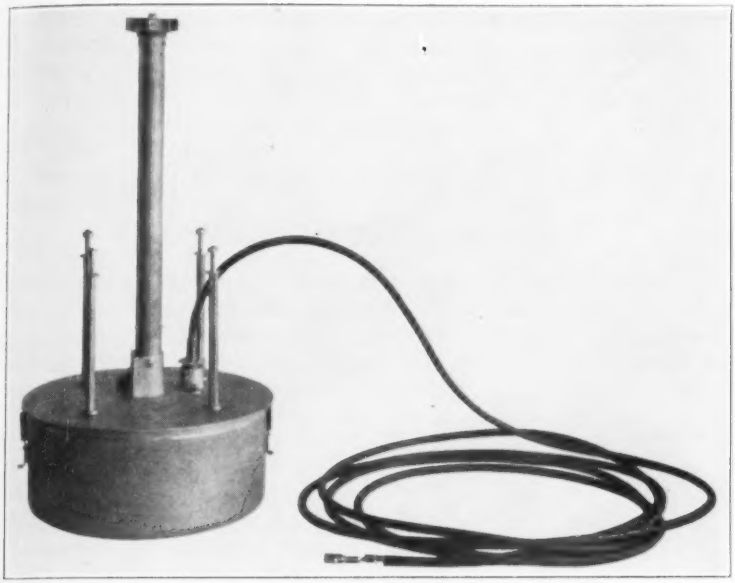
New Magneto Compass

THE magneto compass, recently developed by the General Electric research laboratory as a very sensitive and accurate direction indicating instrument for aviators, has been developed to the commercial stage. This compass is simple in construction, accurate in readings and has but a fraction of the weight of the older types of compass now being used.

The new compass is a remote indicating device, operating on the principle of the earth inductor compass but embodying many improvements. Its chief advantages rest in the use of pole pieces which give the directional effect and, at the same time, concentrate the lines of force of the earth's magnetic field, thereby producing a denser field in which to operate. The older types of remote indicating compasses involve the use of comparatively large rotating armatures with a large number of turns, whereas the rotating armature in the magneto compass is about the size of a walnut, with but a few turns, operating at

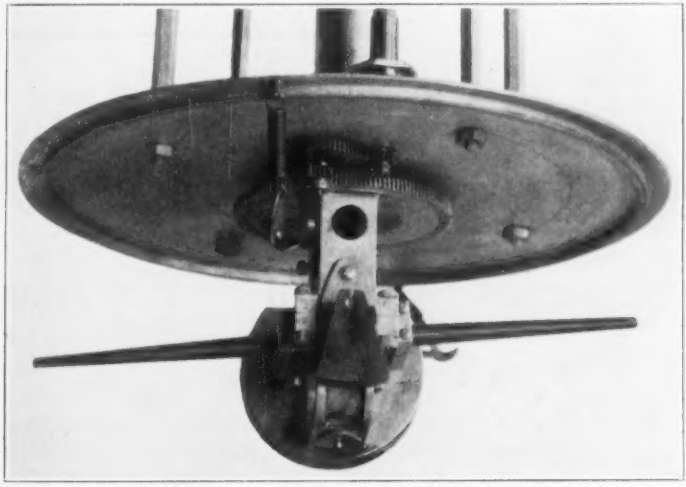
relatively low speed. The complete unit weighs approximately eight pounds net.



Generating Unit with Windmill Drive and Course-setting Flexible Shaft

Advantages include reliability, light weight, simplicity, long life and freedom from electrical and mechanical faults.

The first application of the magnet compass to commercial transport service was made by the Boeing Air Transport, Inc., in its all-



Generating Unit—Cover Removed

plane passenger service between the Pacific Coast and the Great Lakes.

The new transport service will carry mail and passengers between San Francisco and Chicago in 20 hours. This is the longest air line in the world, and involves the greatest variations in altitude and temperature found in any regular transport operations in this country. The airplanes are the largest transports in regular long-distance flight operations in the United States.

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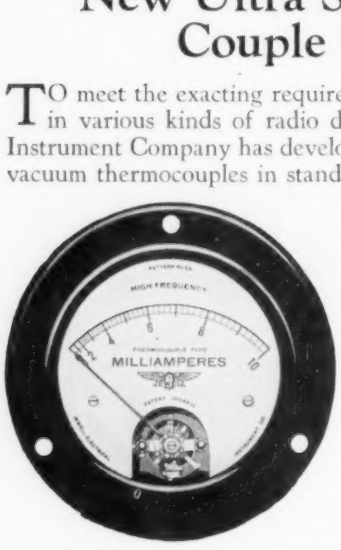
New Ultra Sensitive Thermo Couple Instruments

TO meet the exacting requirements of high frequency measurements in various kinds of radio development work, the Jewell Electrical Instrument Company has developed milliammeters using special internal vacuum thermocouples in standard ranges as low as 10 milliamperes.



The vacuum thermocouple is an improved design, and will handle a 50% overload without difficulty. These instruments are contained in the flush type moulded black bakelite case of the size which is rapidly becoming standard for miniature instruments, namely having a case diameter of 2¾ inches and a flange diameter of 3⅜ inches.

These low range, high frequency instruments are recommended for wavemeter work, as well as for the determination of many circuit constants using radio frequency current. Coil resistance, decrement, parasytic oscillations, and many other determinations may be made, using these sensitive instruments without the necessity of using laboratory type galvanometers with separate thermocouples.

The 10 milliampere range has a resistance across the binding posts of approximately 65 ohms; the 25 milliampere range has a resistance of around 16 ohms; the 50 milliampere instrument has a resistance of about 6.5 ohms; and the 100 milliampere vacuum thermocouple instrument has a resistance of about 2.5 ohms.

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Automatic Control of Hot-Blast Temperatures

(Bristol Company)

FOR the benefit of those not familiar with blast furnace practice it may be explained that the modern furnace requires a supply of air amounting to 40,000 cubic feet or more per minute, at a pressure that may be as high as 30 pounds per square inch. This air is forced by im-

mense blowing engines into the "cold-blast main," and thence, through one of a group of four or five "stoves," to the "hot-blast main," and on to the furnace. These "stoves" form an outstanding feature on every blast furnace installation. They are tall stack-like structures, containing a checkerwork of firebrick, which is heated by combustion of gas from the furnace. Provision is made for quickly disconnecting the gas supply and passing the blast through a freshly heated stove, so that as successive stoves cool a new supply of heat is available for the air to the furnace. While the required temperature at the furnace is likely to lie at a value between 1,100 and 1,300 degrees F., and for most efficient operation should be maintained constant at a definite figure, the temperature of the air as it enters the hot blast main from the stove is an extremely variable quantity, sometimes running as high as 1,500 degrees with a hot stove. As the stove cools this value gradually falls, until it is as low as permissible, when it is the practice to cut in a freshly heated unit and put the other back on the gas.

The alternate heating and cooling of the blast due to the changing of stoves is represented by the curve A in Fig. 1, the blast coming up

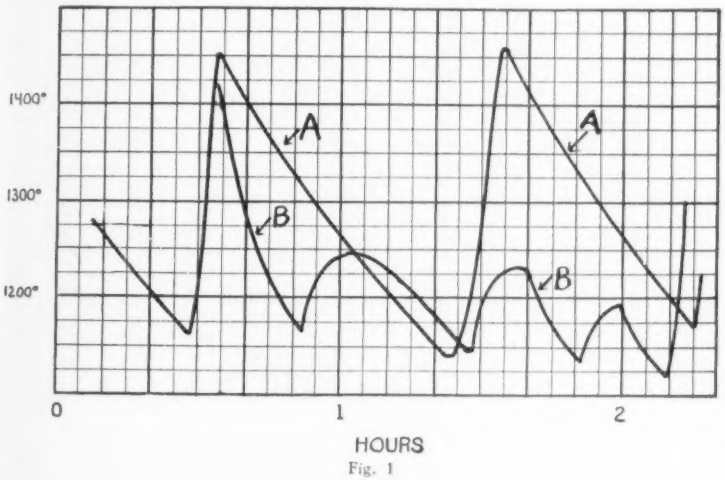

Fig. 1

to its highest temperature very rapidly, and the cooling extending over a period of from one to two hours. As these extremes of temperature are undesirable, both as regards economies of operation and quality of iron produced, as well as having damaging effects on the furnace and associated equipment, it has been customary to effect a certain degree of regulation by means of a "mixing valve," by-passing a quantity of cold air directly into the hot blast main: and in well designed installations the by-pass is so located that a thorough admixture is obtained before the air reaches the furnace. This valve, manually operated, and closely watched, is capable of materially improving conditions in the hot blast main; but since an almost continuous adjustment is required it is already understood why such is seldom accomplished unless the control be made entirely automatic. A temperature curve which well

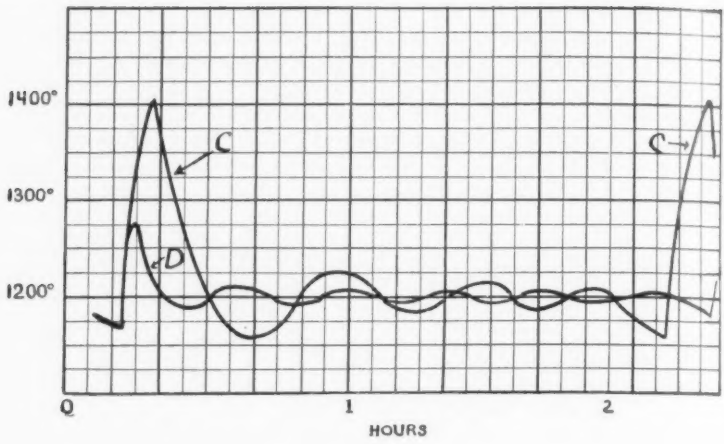

Fig. 2

represents the results obtainable with ordinary hand control is shown at B, Fig. 1. The extremely high temperatures have been somewhat reduced, and the rate of stove cooling materially lessened.

In the automatic regulation of hot blast temperature, the mixing valve is placed under control of a pyrometer actuated in turn by a thermocouple located at a carefully selected point in the hot blast main, where its temperature is representative of that of the air entering the furnace. The pyrometer, through a system of relays, operated the motor-driven valve in such a way as to tend to correct for any change of temperature at the couple. The most elementary form of pyrometer control can be made to give a smoother regulation than could be obtained with any but the most painstaking hand control; and results would be somewhat as represented at C, Fig. 2. But where the temperature of the incoming air varies as it does, sometimes rapidly and sometimes slowly, it is necessary that the valve be capable of operation at more than one speed, and that the controlling instrument be able to select that speed which will best correct for the change. In the Bristol system several equivalent velocities of the valve motor are obtained by adjustable interrupters in the relay circuits; and the settings are made so that the lowest velocities are obtained with small deviations from the temperature for which the instrument may be set, and the higher speeds as the pointer swings farther from the ideal value. The very rapid rise of temperature when a hot stove is first cut in presents a special problem; and to meet this it is necessary that the low speed operation of the valve be suspended, and the valve opened as rapidly as possible, until the full amount of cold air is admitted. In the Bristol system this condition is automatically anticipated, with the result that the objectionable peak is reduced to a negligible value. The curve D in Fig. 2 is typical of the results so obtained; and this theoretical curve is confirmed by the record in Fig. 3, which is reproduced from a pyrometer chart obtained under actual operating conditions.

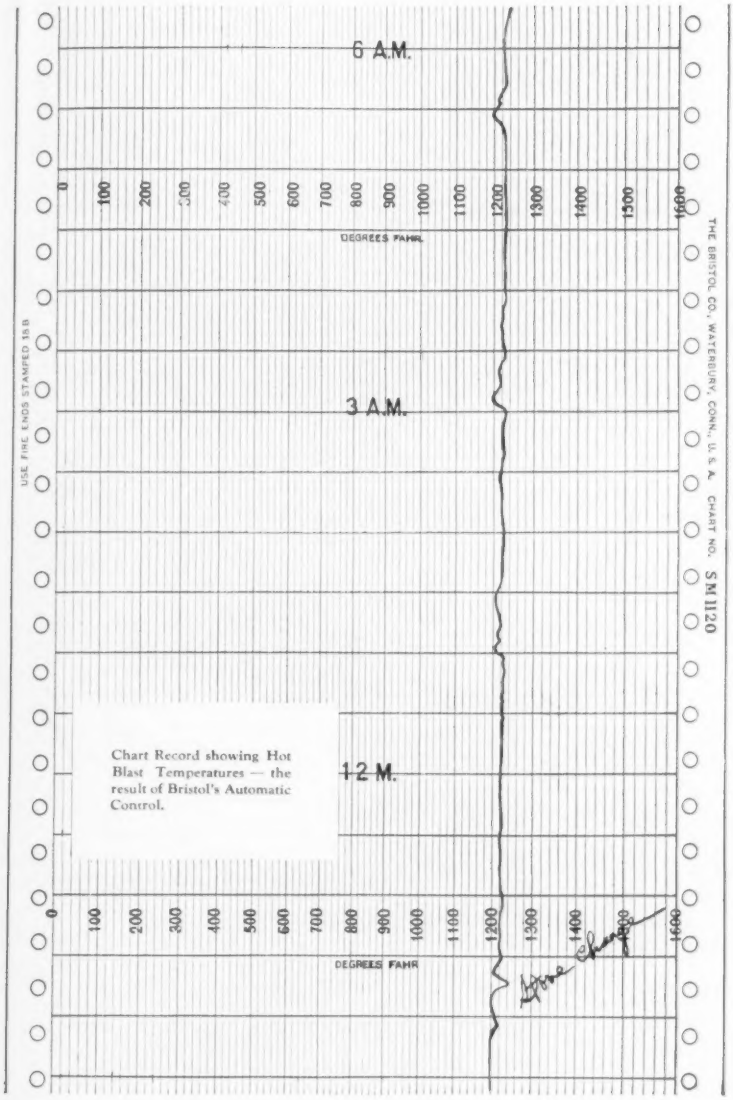
6 A.M.
3 A.M.
12 M.
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600
DEGREES FAHR.
USE FIRE ENDS STAMPED 158
THE BRISTOL CO., WATERBURY, CONN., U. S. A. CHART NO. SM 1120
Chart Record showing Hot Blast Temperatures — the result of Bristol's Automatic Control.

Fig. 3

A typical installation of the control system is shown in Fig. 4. The pyrometer is of the same general type as has long been used in all classes of automatic control. It is direct indicating, requiring no auxiliary battery; and in case of electrical failure there is no interruption to the precise and accurate reading of temperature. By means of an index or "spotter" on the scales, the regulating point may be instantly set to any

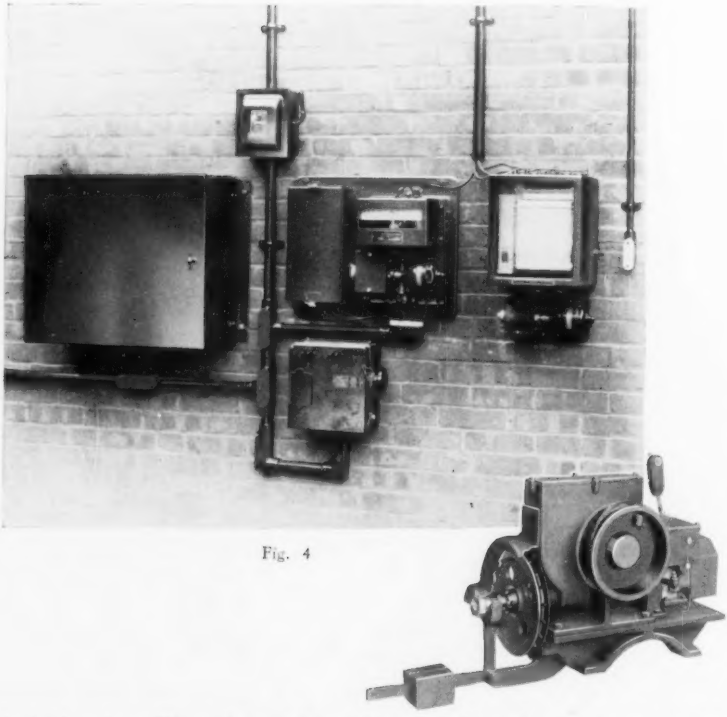

Fig. 4

desired value. The relay system through which the motor is operated is completely interlocked, so that manual control may at any time be superimposed on the automatic without "jamming" the action, the system reverting to full automatic when the manual control is released or when either limit of valve travel is attained. The inset in Fig. 4 shows the operating unit used for cable controlled valves; but the system is equally applicable to gate and butterfly valves. The operating unit may be mounted on a pedestal near the valve, upon a saddle carried by the piping, or in many cases, directly upon the structure of the valve.

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The Treasure Chest

(Thwing Instrument Company)

THE Thwing Treasure Chest is a simple and practical checking set made especially for testing the accuracy of pyrometers and thermocouples. It is so designed and arranged that with it, it becomes a very simple matter to check any type or make pyrometer and thermocouple. The Thwing Treasure Chest combines an entire laboratory equipment into one compact simple unit.

It operates on the potentiometer principle, but it differs from all other potentiometers. Ordinarily a potentiometer is used to measure e.m.f. only. This one not only measures e.m.f. in millivolts but it is so

arranged that it is actually possible to pass a current (millivoltage) from the Treasure Chest and impress it into pyrometers of either millivolt or potentiometer principle, to check their accuracy. By this method checks can be taken at all points of the pyrometer scale or chart. This can be done only with the Thwing Treasure Chest by means of the Electrocite, which is not contained in any other potentiometer.

The Electrocrite is a variable auxiliary circuit by which current is impressed into the instrument being tested in order to check its accuracy. This current can be regulated to correspond to the e.m.f. values of the thermocouple at various temperature points and in this way a pyrometer can be checked at every point on the scale. This is a most valuable feature, for it is quite possible for a pyrometer to be accurate at some points and inaccurate at other points.

The Thwing Treasure Chest has a long scale with a capacity to measure 101 millivolts which is totally unlike the scales used in other potentiometers. The usual potentiometer scale is contained on the slide wire. In the Treasure Chest the scale is divided; the major portion is contained in accurately calibrated steps of fixed resistances in units of 10 from 0 to 90, and only a small portion of the scale is contained on the slide wire. This gives the advantage of the long scale by permitting open divisions in the scale graduations. The scale graduations are in divisions of 0.5 millivolts. Each division is sufficiently open to be easily estimated in values of .01 millivolts. The slide wire scale is calibrated from 0 to 11 millivolts and overlaps each unit by one millivolt. This overlapping scale makes it possible to obtain any combination of e.m.f. values for cross-checking the accuracy of the Treasure Chest at all major divisions on the scale. This feature alone makes the Thwing Treasure Chest a most desirable instrument. It not only provides a

standard for checking, but also provides a means of cross-checking itself.

For testing pyrometers, leads are used to connect the Treasure Chest to the pyrometer and the Electrocrite is adjusted to the e.m.f. values of the thermocouple for which the pyrometer is calibrated. This is done for each major temperature point and a quick check is obtained on the calibration over the entire scale range.

Another exclusive feature in this Treasure Chest is a compensating resistance which can be adjusted to conform to a known external lead resistance in a pyrometer circuit.

A most efficient and quick way of testing a thermocouple against a standard thermocouple is also provided. The two thermocouples are connected to the instrument and by means of a switch, a reading is obtained on each thermocouple, thus checking one against the other.

The Thwing Treasure Chest is unique in construction, with it, it is possible to check all types and makes of pyrometers, whether direct reading millivoltmeter types or potentiometer types. It is equally easy to check both indicating and recording pyrometers. Also when necessary, a pyrometer can be checked without removing from service, by connecting the potentiometer in parallel with the pyrometer and comparing the two readings obtained.

Pyrometers are the guides used in the manufacture of various products. They are as a compass to a pilot on a ship. A pilot wouldn't think of taking his ship out unless the compass had been thoroughly tested and found to be absolutely correct.

The same should be done with pyrometers and thermocouples. They should be tested regularly and frequently to be sure that they maintain their accuracy. The pyrometers in a plant should be a big dividend paying investment. If they are inaccurate, losses occur in the quality of ware, production, fuel and labor. This means less profits. To know pyrometers are accurate is to make certain that products will not suffer. For primarily one is interested in dollars and cents and inaccurate pyrometers mean so many dollars and cents wasted.

The Treasure Chest enables pyrometer users to test and check their own pyrometer equipment and know that the pyrometers are accurate. Knowing at all times that pyrometers are accurate, is so important, that the value of such an instrument cannot be over-estimated. Plant efficiency depends upon such knowledge. High-peak production is maintained and the high quality of product does not suffer.

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INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

DAIRY PROCESSES. *Evert F. Nordstrom.* Consolidated Ashcroft Hancock Company, Inc., Bridgeport, Conn., 1929. Half cloth, 5 x 8 in., 143 pp., 36 figs. Price $2.00.

REVIEWED BY M. BERG RIMBACH

This is Volume III of the American Industrial Instrument Manuals. The need for proper instru-

"U" Gauge

THE Amthor Testing Instrument Co., Inc., have brought out a new, improved "U" Gauge for which a patent has been applied.

It is used for measuring the static pressure in gas lines, ventilating systems, forced draft, etc., and is adaptable for testing purposes as well as for permanent installation.

The gauge is of the double reading type and the indicated pressure is the sum of the two scale readings coinciding with the water levels in the two legs of the U tube.

The scale can easily be adjusted to the zero water level merely by sliding it up or down. It is graduated in inches and tenths of an inch with the zero line in the center. Thus a 6" gauge is graduated 3" above and 3" below the zero line.

The feature of this new gauge is an improved method of packing whereby the U tube is easily replaced in case of breakage with cementing eliminated. The pressure tight connection between the U tube and the head piece is made by a cross plate compressing the two packings simultaneously. This is accomplished by the turning of a single screw.

The U tube is made of annealed glass carefully selected for uniformity of bore. All metal parts are polished, nickel-plated and the scale has a black background with distinct white characters.

This gauge has a union connection with a ⅛" female pipe thread.

It is made in the following sizes: 4", 6", 8", 10", 12", 18", 24", 30" and 36".

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INSTRUMENTS BOOK SHELF

ments in handling, storage and processing as well as the proper arrangement of these instruments is the subject of this volume.

This book contains information of value to every one concerned with the handling of milk or any of its products.

CHEMICAL ENGINEERING CATALOG. Chemical Catalog Company, New York, 1929. Cloth 9 x 12 inches, 1205 pages. Price $3.00 postpaid. Free of charge to operating officials subject to return upon publication of new edition.

REVIEWED BY RICHARD RIMBACH

The fourteenth annual edition of the Chemical Engineering Catalog is divided into the following sections: 1. List of Firms Whose Products Are Cataloged; 2. Trade Name Index; 3. Classified Index of Equipment and Supplies; 4. Equipment and Supplies Section; 5. Classified Index of Chemicals and Raw Materials; 6. Chemicals and Materials Section; and 7. Technical and Scientific Books Section.

The Chemical Engineering Catalog is a collected, condensed and standardized catalog of data of equipment, machinery, laboratory supplies, heavy and fine chemicals and raw materials used in the industries employing chemical manufacturing processes. The classified indexes of such equipment and materials are carefully cross-referenced. The Technical and Scientific Books Section catalogs and describes briefly a very complete list of books in English on chemical and related books.

A very decided improvement appears in this new issue of the Chemical Engineering Catalog in the Classified Index of Chemicals and Raw Materials. Firms listed in this index are marked to denote suppliers of C. P. and U. S. P. and analyzed chemicals, regular commercial grades or obth.

The catalog will give valuable assistance to all who have need for such information.

THE PRACTICE OF SPECTRUM ANALYSIS WITH HILGER INSTRUMENTS. Adam Hilger, Ltd., London, 1929. 4th Edition, Paper 6 x 9¾ inches, 38 pp. Price, 1 s. 6 d.

REVIEWED BY ARTHUR SCHRODER

INSTRUMENTS BOOK SHELF

This concise treatise on the extensive but relatively little understood subject is too valuable not to be in the hands of everyone doing spectroscopic analysis, regardless of the make of the instrument employed. Compiled by F. Twyman, the designer of many Hilger Instruments, its value is greatly enhanced by contributions from E. N. Andrade and S. Barratt of University College, London; S. J. Lewis; D. M. Smith of the British Non-Ferrous Metals Research Association; A. A. Fitch of the Imperial College of Science, New Kensington, and J. W. Ryde of the General Electric Company's Research Laboratories at Wembley. The types of problems to which Spectroscopy is applicable, the apparatus to be used, the means of exciting emission spectra (flame, spark and exploded wire), directions for taking spectrograms, quantitative spectrum analysis and a discussion of the various types of spectrum, are all treated in sufficient detail to warrant the book serving as a guide in the solution of many mineralogical, metallurgical and chemical problems now beyond the scope of chemical analysis. While metals and metalloids are discussed at some length, the gases are not. It is hoped that future editions of the book will include this.

SELECT METHODS OF METALLURGICAL ANALYSIS. *W. A. Naish & J. E. Clennell.* Chapman & Hall, Ltd., London, 1929. Cloth 6 x 9½ inches, 495 pp. Price, 30 shillings.

REVIEWED BY ARTHUR SCHRODER

This book is essentially a reference book of methods for general qualitative and quantitative chemical analysis. "The methods chosen have been selected on account of their accuracy and their general suitability for the purpose in view. Most of them have been actually tried by the authors."

Part I treats of methods of sampling, preparation of sample for analysis and general notes on volumetric analysis.

Part II includes the selected methods for the analysis of the elements arranged in alphabetical order, with particular attention being paid to the rarer elements.

Part III gives the methods of analysis of commercial metals, ferrous and non-ferrous alloys.

Part IV contains the complete analysis of ores, slags and metallurgical by-products as skimmings, dusts, mattes, scrap, etc.

Part V treats of the analysis of refractories and coal, while Part VI contains notes on electrometric titrations, analysis of minerals and spectrographic analysis.

Of the various parts, Part II is particularly noteworthy in its treatment of the rare metals schematically arranged for qualitative and quantitative analysis.

The bibliographies on each metal while sometimes slightly antiquated are, nevertheless, quite comprehensive. The parts dealing with commercial metals and metallurgical by-products are also very complete. But the sections on volumetric ayalysis, coal, electrometric titrations and the analysis of minerals leave much unsaid. Chemical microscopy, hydrogen ion concentration and photo micrography and X-ray analysis, which are now playing so important a part in metallurgical analysis, are hardly mentioned. The Section on spectrographic analysis reads almost like a reprint of some of the publications of Adam Hilger, Ltd.

It is unfortunate that the book in parts, is not more complete, but those parts which are thoroughly covered, give data not compiled elsewhere. This, along with the extensive bibliographies, make it a handy reference work for the chemist and metallurgist called upon for rare analyses.

THE FUNDAMENTALS OF RADIO. *R. R. Ramsey.* Ramsey Publishing Company, Bloomington, Ind., 1929. Cloth 6x9 inches, 372 pages, 375 figs. Price $3.50 Postpaid.

REVIEWED BY RICHARD RIMBACH

In this book, the author endeavored to give the basic theory of radio as it is exemplified in modern practice. An effort was made to give a non-mathematical treatment of the subject, although some calculus was introduced in a few sections. The text is illustrated by a large number of diagrams and pictures, a few typical circuits are given to show how the fundamentals are applied in modern practice.

An unusual arrangement was used in the table of contents and in the numbering of the illustrations. The figures in each chapter are numbered consecutively beginning with number 1 in each case.

Some of the subjects covered: capacity, inductance, radio waves, detectors, vacuum tubes, coupled circuits, aerials, radio instruments, radio resistance, spark transmission, long wave transmitters, vacuum transmitters, radio telephone, receivers, amplifiers, balanced circuits, loud speakers, etc.

EXPERIMENTAL RADIO. *R. R. Ramsey.* Ramsey Publishing Company, Bloomington, Ind., 3rd Edition, 1929. Cloth, 5½x6¾ inches, 255 pages, 168 figs. Price $2.75 Postpaid.

REVIEWED BY RICHARD RIMBACH

The book is essentially a laboratory manual of radio and audio frequency measurements and demonstrations. It includes 128 experiments illustrated by 168 figures and diagrams. The 1929 impression of the third edition has been enlarged and revised to keep up with the rapid changes of radio. New subjects covered are television, filters, attenuators, balanced circuits and acoustical measurements. The book opens with a list of reference books covering this subject. This manual should prove useful to students of radio in physics and electrical courses.

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ANEROID BAROMETERS. List P28 illustrates aneroid barometers and pocket magnetic compasses. This is printed in English. G. Lufft, Stuttgart, Germany.

BALLISTIC INSTRUMENTS. Druckschrift 102 illustrates photo-theodolites, universal cameras, chronographs, high speed moving picture cameras, time settings, electrically driven tuning fork, comparators and instruments for measuring explosion pressures. This is printed in German. Dr.-Ing. Hans Rumpff, Bonn, Germany.

CATALOGUE OF BOOKS ON PHOTOGRAPHY. American Photographic Publishing Co., 428 Newbury St., Boston, Mass.

CONTINUOUS INSPECTION WITH GRAPHIC INSTRUMENTS. Bulletin 1029 illustrates the application of recorders to record the thickness of Celotex sheets as they come from the presses. Another application is to the inspection of airbrakes. Esterline-Angus Co., Indianapolis, Ind.

CUTTING SPEED METER. Leaflet briefly describes a hand cutting speed meter. Printed in English and German. J. Hengstler, Aldingen b. Spaichingen, Germany.

ELECTROCARDIOGRAPH. Mitteilung No. 9 describes a cardiograph with its accessories. This is printed in German. Prof. Dr. M. Th. Edelmann & Sohn, Muenchen, Germany.

COUNTERS. Leaflet describes and illustrates a number of counter types. This is printed in English. J. Hengstler, Aldingen, Germany.

EDDY CURRENT TACHOMETERS. Bulletin No. 218e covers the construction, method of operation, damping, accuracy, etc. This is printed in English. Dr. Th. Horn, Leipzig W 34, Germany.

EOTVOS TORSION BALANCE. Booklet contains a number of questions and answers in regard to the Eotvos Torsion Balance. Dr. George Steiner, Cotton Exchange Bldg., Houston, Tex.

ELECTRICALLY OPERATED LONG DISTANCE TACHOMETERS FOR AEROPLANES. List 302e describes the instrument, its operation and installation and gives prices. Dr. Th. Horn, Leipzig W 34, Germany.

ENGINE-TEMPERATURE INDICATOR FOR AIRCRAFT. GEA-1187 describes and illustrates the instrument, General Electric Co., Schenectady, N. Y.

ELECTRICALLY OPERATED LONG DISTANCE TACHOMETERS. List No. 301e gives information on the construction, method of operation and installation. Dr. Th. Horn, Leipzig W 34, Germany.

GALVANOMETERS THAT MEET THE MOST USUAL NEEDS. This leaflet is a condensed list of L & N galvanometers. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

GAS TESTING APPARATUS. Bulletin AG-2 covers apparatus for calorimetry, sulphur and ammonia test, hydrogen sulphide test, specific gravity, etc. American Meter Co., 991 Broadway, Albany, N. Y.

GENERAL CATALOGUE of vernier calipers, micrometers, T-squares, protractors, limit gauges, etc. This is printed in French. Mauser-Werke A. G., Oberndorf a./N., Germany.

GYRORECTOR. This leaflet describes an instrument used for blind flying. Pyrometer Instrument Co., 50 Howard St., New York, N. Y.

HAIR HYGROMETERS. Price list No. 33 illustrates hair hygrometers and weather stations. This is printed in English. G. Lufft, Stuttgart, Germany.

HAND TACHOMETERS. Leaflet briefly describes the precision hand tachometers. J. Hengstler, Albingen b. Spaichingen, Germany.

INSTRUMENTS FOR HUMIDITY AND TEMPERATURE MEASUREMENT. List T is a condensed catalogue of instruments for the measurement of humidity and temperature in textile, paper and rubber industries. W. Lambrecht, A. G., Goettingen, Germany.

INSTRUMENTS FOR STUDYING SOUND. Bulletin covers tuning forks and pitch pipes. This is printed in German. Prof. Dr. M. Edelmann & Sohn, Muenchen, Germany.

LABORATORY. The recent issue covers the autoconstant temperature viscosimeter, a new micro-balance and the densometer used to test the porosity of cloth, felt, fabric, etc. Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

LABORATORY PRESS. Sheets LP 1 and 2 illustrate the Carver press for a variety of uses. Fred S. Carver, 90 West St., New York, N. Y.

METER TESTING APPARATUS. Apparatus Catalogue AG-1 is devoted to meter provers. American Meter Co., 991 Broadway, Albany, N. Y.

MOLL RECORDING MICROPHOTOMETER. Bulletin MF 29 describes the two types of recording microphotometer for the analysis of photographed spectra. P. J. Kipp & Zonen, Delft, Holland.

MAGNETO COMPASS FOR AIRCRAFT. GEA 1175 describes and illustrates the instrument. General Electric Company, Schenectady, N. Y.

NEPHELO AND ABSORPTIOMETERS FOR WHITE AND MONOCHROMATIC LIGHT. Bulletin EXMON 29 describes an instrument for the measurement of turbidity and absorption. P. J. Kipp & Zonen, Delft, Holland.

ORIFICE METERS. Catalogue EG-2 describes Westcott orifice meters for gas in large volumes also for air, steam, oil and water. Metric Metal Works, Erie, Pa.

PHYSICS LABORATORY APPARATUS. Mitteilung No. 8 covers electroscopes, coil galvanometers, mirror galvanometers, torsion galvanometers, scales for mirror galvanometers, etc. This is printed in German. Prof. Dr. M. Th. Edelmann & Sohn, Muenchen, Germany.

PROJECTION MICROSCOPE. Bulletin describes and illustrates the Vickers projection microscope. W. Watson & Sons, Ltd., 313 High Holborn, London, WC 1, England.

RECORDING DEMAND AND INDICATING DEMAND METERS. Bulletin AG-4 describes the meter proper, the demand device, the operation, the timing element, charts, etc. American Meter Co., 991 Broadway, Albany, N. Y.

RYBAR TORSION BALANCE. Leaflet illustrates the Rybar torsion balance. George Steiner, Cotton Exchange Bldg., Houston, Tex.

STATIONARY TACHOMETERS OF THE GOVERNOR TYPE. List No. 219e gives information on the choice of the most suitable type of tachometer. It describes several types as well as the accessories. Dr. Th. Horn, Leipzig W 34, Germany.

RECORDING CONTROLLERS FOR FURNACES. Circ. 137-P 35-929 illustrates the application of the L & N recorder controller to the control of furnace temperatures. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

STOP WATCH. Leaflet gives applications of the Pastor Watch and Stop Watch combination. Sterling Watch Co., 15 East 26 St., New York, N. Y.

SURVEY STEREOSCOPE AND CONTOUR PLOTTER. Leaflet describes instrument and gives prices. Adam Hilger, Ltd., 24 Rochester Place, London, N. W. 1, England.

SPECTROGRAPHIC OUTFITS FOR METALLURGICAL ANALYSES. Bulletin dated September, 1929, is to serve as a guide to the choice of suitable spectrographic apparatus for a technical laboratory. Adam Hilger, Ltd., 24 Rochester Pl., London, NW 1, England.

STANDCO MEGOHMERS IN THE STEEL INDUSTRY. Leaflet 491 describes the use of the "2 in 1" megohmer at the plant of the A. M. Byers Co. Herman H. Sticht & Co., 15 Park Row, New York, N. Y.

STRING GALVANOMETER. List 32 has a short historical sketch on the string galvanometer, and then describes the instrument, for photographic recording. Prof. Dr. M. Th. Edelmann & Sohn, Muenchen, Germany.

SIPHON GAUGES AND THERMOMETERS. Bulletin AG-5 covers the bent glass siphon gauge. American Meter Co., 991 Broadway, Albany, N. Y.

TORSION BALANCE PRINCIPLES AS APPLIED BY THE ORIGINAL EOTVOS TORSION BALANCE. Reprint of a paper appearing in the bulletin of the American Association of Petroleum Geologists. George Steiner, Cotton Exchange Bldg., Houston, Tex.

THICKNESS GAUGE. This leaflet describes a hand dial thickness gauge. Printed in four languages. J. Hengstler, Aldingen b. Spaichingen, Germany.

TECHNICAL INSTRUMENT BULLETIN. The November issue contains the following: The Busch Color Film in Natural Science and Medical Instruction; and Some New Photographic Apparatus. Emil Busch Optical Co., Ltd., 37 Hatton Garden, London, England.

VAN CITTERT'S DOUBLE MONOCHROMATORS WITH OPTICAL SYSTEMS OF GLASS OR QUARTZ. Bulletin MONO 29 describes the glass double and the quartz double monochromator. P. J. Kipp & Zonen, Delft, Holland.

WET AND DRY TEST METERS. Bulletin AG-3 describes portable test meters. American Meter Co., 991 Broadway, Albany, N. Y.

AVIATION CLOCK. Leaflet illustrates and describes an aviation clock manufactured by the Waltham Watch Co. Pioneer Instrument Co., 754 Lexington Ave., Brooklyn, N. Y.

GENERAL CATALOGUE. Bulletin No. 351e describes and illustrates the products of Dr. Th. Horn, Leipzig W 34, Germany.

ASPIRATING PYROMETER. Leaflet SH-2853 illustrates the aspirating pyrometer for accurate temperature measurements on moving gases. This literature is printed in German. Siemens & Halske A. G., Berlin-Siemensstadt, Germany.

BLAETTER FUER UNTERSUCHUNGS UND FORSCHUNGS INSTRUMENTE. This house organ contains articles pertaining to the products of Emil Busch A.G., Rathenow, Germany. This is printed in German.

CATALOGUE OF CHEMICALS. List of chemical and prices. J. T. Baker Chemical Co., Phillipsburg, N. J.

CHEMIST ANALYST. The May 1st issue contains a number of articles of chemical analysis methods. J. T. Baker Chemical Company, Phillipsburg, N. J.

HYDROMETERS. This leaflet gives information on hydrometers, salinometers and densimeters, as well as accessories. List "O" Heath & Co., Ltd., New Eltham, London, S.E. 9, England.

MICROSCOPES. This 92-page catalogue covers microscopes and accessories manufactured by C. Baker, 244 High Holborn, London W.C., England.

NAVIGATIONAL INSTRUMENTS 1928-1929. A 48-page booklet containing information on barometers, chronographs, compasses, hydrometers, sextants, slide rules, sounding machines, stop watches, telescopes, thermometers, etc. Heath & Co., New Eltham, London, S.E. 9, England.

OPACITY METER. The Aminco Opacity Meters for testing the transparency of print paper, tracing cloth, etc., are described in Bulletin 506. American Instrument Company, 774 Girard St., N.W., Washington, D. C.

TACHOMETERS. Catalog 1240 gives complete information on "Frahm" Vibrating Reed Tachometers. James G. Biddle, 1211 Arch St., Philadelphia, Pa.

TRUCK TYPE SWITCHBOARDS. Leaflet 20379 contains detailed descriptive material on the application, distinctive features, and construction of truck type switchboards. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

TURBO HUMIDIFIER. Bulletin 424 describes the turbo humidifier as a means of humidification. Parks-Cramer Company, Fitchburg, Mass.

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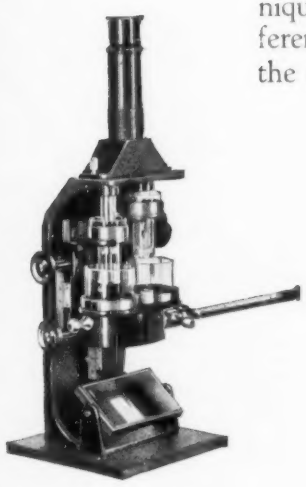
THE Bausch & Lomb Hydrogen-Ion Colorimeter is built according to the design of Professor A. B. Hastings of the University of Chicago and the principle used by Mines (1910) and Gillespie (1923). This model is based on the standard Duboscq Colorimeter, additional cups being provided for the use of both alkaline and acid forms of the indicator in either light path. Further auxiliary cups provide for the balancing of body color according to the Walpole technique, in cases where such interference prevents the matching of the colors due to the indicators.



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CURRENT LITERATURE REVIEW

Abstracts on instruments and devices for measurement, inspection and control.

The Technology Department, Carnegie Library, Pittsburgh, Pa., will furnish photostats of material abstracted here. Negative prints are 35 cents per page, plus 10 cents for mailing (first class). All orders should be paid in advance. The library is not responsible for loss in mails.

Modern Instruments for Seismic Prospecting. R. Ambronn. Engg. Min. Jl., July 20, 1929, pp. 93-99.

Translated into English by E. von Buelow. A new type of seismograph which registers electrically the acceleration of the earth movement rather than the total movement registered by the mechanical seismographs is announced. Because of the electrical registration, very high amplification is possible. Several receivers and the shot time line are connected to a multiple unit recording galvanometer and record on a single film. Time can be measured to 0.001 second. Considerable discussion is given of the advantages of an electric seismograph registering acceleration contrasted with the disadvantages of the mechanical seismograph registering total movement.

Sound Recording—The Blattner System of Electro-Magnetic Recording and Reproduction. Electrician, Oct. 18, 1929, pp. 472.

L. Blattner of the Blattner Color & Sound Studios has demonstrated a new process. The sound waves are impressed on to a microphone which converts the acoustic vibrations into electrical vibrations, and these are conducted into the coils of electromagnets. Past the cores of these a thin steel tape or wire is made to move at a constant speed. The electrical vibrations are recorded and fixed as magnetic vibrations on the tape or wire. Reproduction is effected by the reverse process. The different magnetic values of the tape or wire influence the small cores of the electro-magnets, giving rise to current impulses, which are made to influence a loud speaker or telephone diaphragm. Outstanding points are indicated.—W.H.B.

Bridge Ohmmeter. Electrician, Oct. 11, 1929, pp. 436.

An instrument combining an ohmmeter and Wheatstone bridge is manufactured by the Record Electrical Co., Ltd. of Broadheath, Manchester, and permits the measurement of low resistances such as are met with in ordinary general industrial work. The instrument has four essential units: a generator for producing the necessary current at high pressure, a direct-reading ohmmeter convertible into a galvanometer for bridge tests, a decade resistance box with radio switch in one arm of the Wheatstone bridge, and a multiple contact switch for changing connections from an ohmmeter to a Wheatstone bridge, all arranged in a portable carrying case complete with handle and shoulder strap. Each unit is described briefly.—W.H.B.

Estimating Iron in Chromium Alloys. Electrician, Oct. 11, 1929, pp. 428.

The method is based on the oxidation of chromium by ammonium persulfate and then precipitation of the iron with ammonia. A 1-3 gram sample is dissolved in acid—dilute sulfuric where possible and hydrochloric or aqua regia, if necessary followed by addition of sulfuric acid and fuming. The solution is diluted with hot water and boiled, the silicon removed, if present, and the solution cooled and diluted to 250 cc. and an aliquot containing .1-.2 grams of iron used. This portion is diluted to about 150 cc., 2 grams of persulfate added and the solution boiled. Ammonium chloride and hydroxide are added and the iron determined as ferric oxide. Nickel may be determined by the dimethylglyoxime process in the filtrate.—W.H.B.

Electrostatic Voltmeters. Electrical World, Nov. 2, 1929, pp. 913.

The Delta Star Electric Co., Chicago, Ill. has marketed a laboratory type electrostatic voltmeter operating on the principle of repulsion of similar charges and designed for voltages up to 100,000. Fixed spheres are connected to the potential to be measured and the shaft of the pivoted spheres carries a galvanometer mirror reflecting a light beam on a calibrated scale. The voltmeter measures the root mean square or the peak voltage according to the connection.—W.H.B.

Construction and Operating Characteristics of Neon Tubes. Joseph Henry O'Neill. Electrical World, Nov. 9, 1929, pp. 928-9.

For neon signs from 5000-10,000 volts are required for 50 ft. of tubing which is divided into 5 ft. sections of glass. The high voltage is developed from the usual house current of 110 volts by a step-up transformer. Since the high voltage is confined to the cables within the sign box, neon signs must be well constructed. Construction peculiarities are pointed out, also the factors determining the life of the tubes. A peculiarity of neon is that the greatest efficiency in lumina per watt is secured with tubing of small diameter. Neon light consumes about 1/5 to 1/10 the current required for a lamp display of equal power.—W.H.B.

New Principle in Micrometer Caliper. American Metal Market, No. 220, Nov. 13, 1929, pp. 7.

Brown & Sharpe Mfg. Co. of Providence, R. I. have marketed a caliper with a range of from 0 to 1 inch by ten-thousandths, reading the ten-thousandths' parts directly. It is called Micrometer Caliper No. 24. The thousandths are read from the band and thimble and the readings in ten-thousandths from a small thimble. Operation is similar to that of the conventional 1-inch micrometer.—W.H.B.

Testing of Tapered Normal Threads (Die Prüfung konischer Normalgewinde). F. Goepel. Werksstattstechnik, Oct. 15, 1929, pp. 586-590.

The starting point of the investigations are the Pipe specifications of the American Petroleum Institute, dated January, 1928. The Physikalich-Technische Reichsanstalt, Berlin, developed new instruments to measure the pitch diameter at the gage point, the major diameter at the gage point and the taper. The equipment to determine lead and lead error and those to determine the flange angle are described. The results are compared with those obtained by the investigations of the Bureau of Standards.—G.N.

(Current Literature Review Continued on Page 16)

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CURRENT LITERATURE REVIEW

Application of Plane Diaphragms Instead of Collodion Bags for Dialysis and for Determination of Osmotic Pressure of Colloidal Solutions (Ueber die Verwendung planer Membranen an Stelle von Kollodiumsaeckchen zu Dialysezwecken und zur Bestimmung osmotischer Drucke kolloidaler Loesungen). J. Zakowski, Chem. Fabrik, Sept. 25, 1929, pp. 199-202.

Lack of accuracy of the convential instruments led to the improvements described in the paper.—E.F.

Color Measurements With the Moll Extinctiometer (Kleurmetingen met Behulp van den Extinctiemeter van Dr. Moll). M. J. van Tussenbroek, Chemisch Weekblad, July 13, 1929, pp. 374-381.

A method is given for carrying out color measurements by means of Dr. Moll's Extinctiometer and the use of glass-filters of Schott Co., Jena. Examination is made by measuring a solution of "Fettponceau L.B." and "Ceresgelb I" in paraffin oil. The results of the measurements agreed very well with the calculated ones. It was possible to measure for instance the bleaching of sesam oil by means of "Norit" in three ways, the results of which led to the same conclusion. The short time required by this method is a valuable asset besides the extreme sensibility and the independence of the subjective observation error, due to eye fatigue.—E.F.

Automatic Regulators and Their Utilization in Glass Industry (Die Selbstregler und ihre Verwendung in der Glasindustrie). O. Knapp. Glas-Industrie, Sept. 1929, No. 1, pp. 167-170; Sept. 1929, No. 2, pp. 179-180.

The paper contains a review of modern automatic regulators including the Arca pressure and Arca-thermo-regulator, the Reinecke types, the Cambridge, Bristol-Fuller, Tycos and Wilson-Maculen regulator, the Thyratron of the G.E. Co., the pressure regulator of Allgemeine Vergasungsgesellschaft and of Schaeffer & Budenberg. Their utilization for purposes of glass industry is outlined.—E.F.

The Belt Testing Machine of Skutsch-Reiman (Die Riemenpruefungsmaschine Skutsch-Reimann). H. Schoenherr. Glasers Annalen, Sept. 15, 1929, pp. 88-92.

The principles involved in the testing machine are given mathematically and graphically. Deficiencies encountered in this kind of measurement are critically discussed, and results collected from 52 tests are presented. The author considers in conclusion the possibilities of the new method.—E.F.

Testing of Rail-Scales of More Than 50 Ton Capacity in Regard to Deflection (Die Pruefung von Gleiswaagen ueber 50 t. Wiegegaehigkeit auf Bruckkendurchbiegung). M. Raudnitz. Glasers Annalen, Sept. 1, 1929, pp. 73-80.

The testing method is fully outlined and all interesting data assembled in 13 tables.—E.F.

Application of the Planimeter for the Determination of Multiple Integrals and for Investigation of Partial Differential Equations (Verwendung des Planimeters zur Bestimmung mehrfacher Integrale und zur Intergration partieller Differentialgleichungen). D. Wehage. Zs. Instrument, Sept. 1929, pp. 425-444; Oct. 1929, pp. 478-496.

This thesis confines itself to the customary polar-planimeter and only exceptionally uses the linear-planimeter, but not the integrator. The following problems are tackled: centrifugal moment, polar moment of inertia of a body, probability calculations, medium geometric distance, heat radiation of various bodies, and application of the instruments for integration of various partial differential equations.—E.F.

On the Stereoscopic Ability of Distinguishing Level Differences (Ueber das stereoskopische Tiefenunterscheidungsvermoegen). M. Maurer. Zs. Instrument, Sept., 1929, pp. 444-457.

Influence of shape of objects, irradiation and light contrasts, fatigue of eyes on fixation if center of level-sill and its significance. Practical example of aerial measurement.—E.F.

Mechanical Aid For Construction of Parabola, Hyperbola, and Arched Curves (Mechanische Hilfsmittel zur Erzeugung von Parabeln, Hyperbeln und Steigbogen). J. Fritzen. Zs. Instrument, Sept. 1929, pp. 457-464; Oct. 1929, pp. 507-512.

The abundantly illustrated paper reviews all mechanical devices employed for the construction of various curves.—E.F.

Levelling Instrument With New Device for Tilting the Telescope Including the Level (Nivellierinstrument mit einer neuartigen Vorrichtung zum Kippen des Fernrohrs mit der Libelle). P. Werkmeister. Zs. Instrument, Sept. 1929, pp. 464-465.

The improvement of levelling instruments of the Sickler Co., Karlsruhe are described.—E.F.

Checking of a Theodolite for Measuring Photographs in Combination with an Aerial Camera (Die Pruefung und Berichtigung eines Bildmesstheodolits in Verbindung mit einer Luftbildmesskammer). P. Samel. Bild. u. Luftbild, June, 1929, pp. 74-86.

The theodolite according to Hugershoff-Heyde is illustrated and described and the mathematical principles given when used in combination with an aerial camera.—E.F.

The SO-Cable (Das SO Kabel). K. Konstantinowsky. E. u. M. Wien, Sept. 8, 1929, pp. 778-783.

The new SO principle in cable-technique is outlined. Tests and instruments to determine magnetic and thermal properties are given.—E.F.

What May Industry Expect from Investigations of Materials with X-Rays (Was kann die Technik von der Materialuntersuchung mit Roentgenstrahlen erwarten?) M. Jona. E. u. M. Wien, April 21, 1929, pp. 322-329.

Survey of the possibilities of X-ray examinations are outlined and empirical application to the solution of the plant problems is urged without waiting for further results of research laboratories.—E.F.

Adjustability of Calibration-Stations and Their Economical Significance for Power Plants (Die Regulierungsfaehigkeit bei Eichstationen und deren wirtschaftliche Bedeutung fuer die Elektrizitaetswerke). W. Janicki. E. u. M. Wien, Sept. 8, 1929, pp. 784-787.

Calibration arrangements for alternative current networks of Landis & Gyr Co. are considered. —E.F.

(Current Literature Review Continued on Page 18)

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CURRENT LITERATURE REVIEW

The Optical Chronograph (Der optische Chronograph). H. Rumpff. Zeitschrift fuer das gesammte Schiess-und Sprengstoffwesen, Feb. 1929, pp. 55-57.

This article reports on the optical chronograph, an oscillograph with very high paper or film speed, and details some of the following applications: Measurement of generators, velocities of detonation, duration of flames and intensities of flames of explosives, pressure development in bomb and guns, initial speed of projectiles and their flight time, investigations on powdered coal explosions, fuses, etc.—E.F.

Determination of the Specific Gravity with the Bunsen Schilling (Bestimmung des spezifischen Gewichtes mit dem Bunsen-Schilling). L. Zipperer. Gas Wasserfach, July 13, 1929, pp. 690-692.

Formulae and practical examples for the determination of the specific gravity of gases with the Bunsen-Schilling.—E.F.

Determination of CO_2 in Gases if Acetylene is Present (Die Kohlensaeurebestimmung in Gasgemischen bei gleichzeitiger Anwesenheit von Acetylen). H. Friedrich. Chem. Zg., Sept. 11, 1929, pp. 706-707.

Apparatus and determination of CO_2 and C_2H_2.—E.F.

On the Determination of Paraffine Hydrocarbons in Motor Fuels by Sulphurising (Zur Bestimmung von Paraffinkohlenwasserstoffen durch Sulfurierung). G. Kuhn. Chem. Zg., Sept. 7, 1929, pp. 701-702.

Critical discussion of methods as to quantitative determination of benzene and benzole in motor fuels.—E.F.

Automatic Instruments in Sugar Industry (Automatische Messgeraete in der Zucker industrie). Chem. Ztg., Sept. 11, 1929, pp. 708.

Apparatus regulating liquid quantities in regard to pressure, time and liters per min.—E.F.

A Magnetic Material Testing Method (Eine magnetische Materialpruefungsmethode). W. Gerlach. Metallwirtschaft, Sept. 6, 1929, pp. 875-877.

Reports on a new suitable method which reveals inhomogenities, failures, etc., in ferro-magnetic material by means of magnetic measurements and invites industry to render this method available for commercial purposes.—E.F.

The Viscosimeter of B. Marschalko (Das Viskosimeter nach Ing. B. Marschalko). F. Feher. Petroleum, Oct. 9, 1929, pp.8-9.

The main disadvantages of the customary viscosimeters are fully outlined and the improvements of the new instrument given. The latter mainly consists of two co-axial metal cylinders the annular slit of which holds the liquid to be tested. The exterior cylinder heated by a special electrical device, is rotated. The rotary movement is transferred on to the interior cylinder due to the force of friction and to the viscosity of the liquid. The interior cylinder is kept in equilibrium by a counter-acting measurable braking force.—E.F.

Methods and Apparatus for Referee Analysis in the Italian Petroleum Industry (Methoden und Apparate fuer Schiedsanalysen in der italienischen Mineraloelindustrie). G. Weiss. Petroleum, Oct. 9, 1929, pp. 11-13.

Survey of chemical and physical testing methods in Italian petroleum industry after standardization.—E.F.

On a Simple Electron Tube Apparatus for Carrying Out Electrometric Volumetric Analysis (Ueber eine einfache Elektronenroehrenapparatur zur Ausfuehrung elektrometrischer Massanalysen). U. Ehrhardt. Chem. Fabrik, Oct. 9, 1929, pp. 443-445; Oct. 16, 1929, pp. 455-457; Oct. 23, 1929, pp. 463-465.

An installation is described which used the electron tube as a static voltmeter for the measurement of potential differences in potentiometric and conductometric volumetric analyses. Further progress refers to titrating apparatus which is firmly connected with the measuring apparatus permitting all kinds of electrometric volumetric analyses without changes pertaining to apparatus simply by modifying the electrical connections.—E.F.

Pressure Reducing Valves and Pressure Regulators (Druckminderventile und Druckregler). K. Schiebl. Chem. Fabrik, Oct. 9, 1929, pp. 446-448.

Process of steam expansion in the I-S-diagram. Directly operating regulators, designated as pressure reducing valves, their peculiarities and range of application. Indirectly acting regulators, their mode of operation, advantages and accuracy. Special apparatus such as overflow and limiting regulators, temperature, moisture and other regulators.—E.F.

A Distributor for Samples Particularly for Screen Analysis (Ein Proben feinverteiler, inbesonder fuer Siebanalysen). F. G. Hoffman. Chem. Ztg., Sept. 18, 1929, p. 728.

Apparatus intended to overcome the difficulties of saving samples from materials consisting of different grain.—E.F.

Careful Evaporation at Low Temperatures. Direct Condensation of Vapors on Water or Ice (Schonende Verdampfung bei niedriger Temperatur. Direktes Kondensieren der Daempfe auf Wasser oder Eis). E. Jantzen & H. Schmalfuss. Chem. Fabrik, Aug. 28, 1929, pp. 387-391.

Paper states how to quickly and easily concentrate by evaporation at temperatures around the ice point.—E.F.

Dangers of Sewer Gases in Chemical Plants, Their Detection and Measurement (Gefahren der Kanalgase in chemischen Fabriken, ihre rEkennung und Messung). A. Ringel. Chem. Fabrik, Sept. 18, 1929, pp. 415-417; Sept. 25, 1929, pp. 429-430.

Examination according to the old method with the Pieler Lamp. Modern inspection with diffusion indicators. Explosion limits of sewer gases. Combating methods.—E.F.

Notes on Heat Meter (Einiges ueber Waermezaehler). H. Windelmann. Chem. Fabrik, Sept. 18, 1929, pp. 419-420.

Construction and mode of operation of more modern heat meters and their possibilities of utilization in chemical industry are discussed.—E.F.

(Current Literature Review Continued on Page 20)

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CURRENT LITERATURE REVIEW

A Portable Radio Intensity Measuring Apparatus for High Frequencies. J. Hollingworth and R. Naismith. Jl. Inst. E. E., Aug. 1929, pp. 1033-1044.

This paper describes a high frequency radio apparatus capable of measuring in absolute units the intensity of the electromagnetic field over the frequency band of 5 to 12 megacycles per sec. It is easily portable, since the total weight without batteries is only 60 lb. An untuned antenna, which is coupled to the grid of the detector tube in an unusual manner, is used to pick up the energy to be measured. Sensitivity is not seriously affected since the range of intensities which can be measured is from 10 microvolts per meter to 10,000 microvolts per meter. The screening difficulty is lessened by using a resistance attenuator and toroidal inductances, and by totally disconnecting the aerial during calibration. The set consists of a detector tube with which is associated a control tube. One stage of audio-frequency amplification follows the detector, and a diode used as a second detector allows a galvanometer to be used for the single comparison. A separate heterodyne is used to obtain the audio frequency. A resistance method is used to attenuate the current from the local source. The complete apparatus has been subjected to a series of tests in self-consistency and absolute value, and these are described in the paper.

Control and Adjustment of Surveys with the Magnetometer or the Torsion Balance. Donald C. Barton. Bulletin of the Amer. Assc. of Petroleum Geologists, Sept. 1929, pp. 1163-1186.

Some degree of residual errors is present in practically every observation with a magnetometer or a torsion balance. Errors of some types can be avoided, or greatly reduced, by careful technique of observation. Other errors can be reduced by the application of corrections, but in general some residual error will persist. Errors in isolated or widely separated observations or, in general, in single lines of stations, are not detectable or at least are not strikingly evident. But if the stations are so placed that there are closed circuits of observations, the errors generally produce more or less discordance. Adjustment of mutually discordant systems, or sets of stations, is necessary for their satisfactory use for all but the rougher interpretation. The adjustment gives a probable value for each station with due regard to all of the observations more or less mutually affecting it. Various types of control and an adjustment are in use. The method of least square adjustment is the most accurate of the methods of adjustment, but requires at least moderate mathematical skill and is distinctly tedious. But for the degree of accuracy in commercial geophysical work in oil geology, certain approximate schemes of least-square adjustment can be cast in simple tabular forms, which are easy to use and which require no knowledge of higher mathematics.

Motor Control for Wind Tunnel. William E. Lewis. Jl. A. I. E. E., Sept. 1929, pp. 686-691.

A wind tunnel for testing model airplanes and their parts, requires accurate control of the air velocity. This paper describes a tunnel having electric drive for producing the air movement and explains a system of control, which allows a wide range of speeds and holds the speed very constant at any set value. Either hand or automatic regulation may be employed. The hand control is used for fairly constant speed while the automatic control gives very close regulation.

Accuracy of Gas Determination Methods (Messgenauigkeit der Gasuntersuchungsmethoden). A. Schneider. Gas Wasserfach, Aug. 24, 1929, pp. 824-832.

The paper presented at the 70th Annual Meeting of the Deutscher Verein von Gas und Wasserfachmaenner, June 10-11, 1929, Berlin, critically discusses determinations of calorific power, specific gravity, hydrogen sulfide, ammonia, oxygen and naphthalene in gas. Includes discussion. —E.F.

The Measurement and the Recording of Instantaneous Light Variations by Means of the Photoelectric Cell and Stabilized Oscilloscope. W. E. Meserve. Trans. Ill. Engg. Soc., Sept. 1929, pp. 671-683.

This paper describes the development and construction of a photoelectric cell and stabilized oscilloscope capable of measuring and recording instantaneous light variations. A detailed explanation of the apparatus and circuits employed is given, together with illustrations of flicker curves obtained from several types of lamps operated on 30-cycle and 60-cycle alternating current.

A Measurement of the Sound Pressure On an Obstacle. W. West. Jl. Inst. E. E., Sept. 1929, pp. 1137-1142.

An investigation of the performance of a small condenser transmitter under different conditions of a test is described in Part 1. The results are reduced to terms of the augumentation of the sound pressures at the surface of the transmitter, considered as an obstacle in a sound field; and a comparison is made with the calculated pressures developed on a spherical obstacle. In Part 2, which is of the nature of an appendix, the accuracies of the methods of measurement are discussed.

A Precise Electrometer Method for Voltage Transformer Testing. R. S. J. Spilsbury. Jl. Inst. E. E., Sept. 1929, pp. 1143-1146.

The paper deals with the determination by a sensitive electrostatic method of the ratios and phase angles of voltage transformers. The method is described and the theory given, including small corrections which arise in its use. A comparison of this method with another of similar sensitivity, of which a short description is included, indicate that no serious systematic errors are present.

The Rotor Bearings of Electricity Meter. W. Lawson. Jl. Inst. E. E., Sept. 1929, pp. 1147-1166.

In this paper on accumulation of experimental and statistical data which have been obtained by the author has been brought under review for the purpose of discussing the leading problem in the sphere of meter maintenance, namely, that of worn bearings. Attention is drawn to the necessity for improving the reliability of meters in service in consequence of the vast number to be dealt with under modern conditions. The period of sustained accuracy needs to be extended in order to reduce the work of periodically exchanging meters, which is becoming increasingly difficult to contend with. It is submitted that the solution has in increasing the durability of the bearings and particularly the combination of bottom jewel and pivot which constitute the footstep of the bearing.

(Current Literature Review Continued on Page 22)

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Rubicon Company

COIL TESTING EQUIPMENTS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.

COLORIMETERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.

COMBUSTION CONTROL EQUIPMENT
Brown Instrument Co.
Leeds & Northrup Co.

COMPASSES
Taylor Instrument Companies

COMPARATORS
Federal Products Corp.

CONDENSERS—Electrical
Leeds & Northrup Co.
Rubicon Company

CONDUCTIVITY METERS
Indicating, Recording, Controlling
Leeds & Northrup Co.

CONSTANT SPEED & FREQUENCY SETS
Leeds & Northrup Co.

CONCENTRATION RECORDERS
Leeds & Northrup Co.

CONTOUR MEASURING PROJECTOR
Bausch & Lomb Optical Co.

CONTROLS, AUTOMATIC

Condensation
Tagliabue Mfg. Co., C. J.

Damper
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

Feed Water
Brown Instrument Co.

Filter Rate
Brown Instrument Co.
Builders Iron Foundry

Float
American Radiator Company

Gravity
Tagliabue Mfg. Co., C. J.

Humidity
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Humidity & Temperature
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Liquid Level
American Radiator Co.
Bristol Company
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.

Motor
American Radiator Company

Pressure & Vacuum
American Radiator Company
Brown Instrument Co.
Bristol Company
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Pyrometer
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.

Refrigeration
American Radiator Company
Brown Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

Special
Rubicon Company

Tachometer
Brown Instrument Co.
Leeds & Northrup Co.
H. Z. Schniewind

Temperature-Time
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.

Thermometer
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.

Thermostat
American Instrument Company
American Radiator Company
Bristol Company
Brown Instrument Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.

Thickness
H. Z. Schniewind

Time
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.

Vacuum
Brown Instrument Co.

Unit Heater
American Radiator Company

Valve——Motor Operated
American Radiator Company
Bristol Company
Brown Instrument Co.
Taylor Instrument Companies

Water Level
American Radiator Company
Bristol Company
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.

COORDINATOGRAPHS

COUNTERS—Revolution
Bristol Company
Brown Instrument Co.
Lehmann & Michels
H. Z. Schniewind

Stroke
Bristol Company
Lehmann & Michels

CURRENT RECORDERS
Leeds & Northrup Co.

CURRENT REGULATORS
Westinghouse Elec. & Mfg. Co.

CYCLE COUNTERS

CYLINDERS-GRADUATED
Tagliabue Mfg. Co., C. J.

DECELEROMETER

DEFORMETER (Beggs)
Southwark Fdy. & Mach. Co.

DEMAND METERS
Westinghouse Elec. & Mfg. Co.

DENSITOMETERS
Akatos, Inc.

DENSOMETERS
H. Z. Schniewind

DIVIDING HEAD

Optical
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

DRAFT GAUGES—see Gauges

(Buyers' Guide continued on Page 23)

CURRENT LITERATURE REVIEW

New Instruments and Methods of Photogrammetric Exploration of Unexplored Territory (Neue Geraete und Methoden fuer die photogrammetrische Erschliessung unerforschter Gebiete). O. Aschenbrenner. Bild. u. Luftbild., March, 1929, pp. 30-38.

Paper presented at the Deutsche Gesellschaft fuer Photogrammetrie, Oct. 19, 1928.—E.F.

Measurement of Temperature of Flames (Messung der Temperatur von Flammen) Litterscheidt. Gas Wasserfach, Aug. 31, 1929, pp. 870-872.

The author fully describes the results of Loomis and Perrott obtained in the Flame Laboratory, Pittsburgh Experiment Station.—E.F.

Discoloration by Radium Rays as an Aid to Technical Investigation (Die Verfaerbung durch Radiumstrahlen als Hilfsmittel technologischer Forschung). D. Przibram. E. u. M. Wien, Sept. 15, 1929, pp. 815-816.

Results from experiments with rock salt are stated and further extension of the unique method is urged.—E.F.

Gas Analysis (Gasanalytisches). E. Ott. Gas Wasserfach, Aug. 31, 1929, pp. 862-863.

The article deals with: (a) complete technical gas-analysis in a closed arrangement and (b) with the new closed arrangement for the determination of incombustible fraction, i.e., CO_2 and N_2. —E.F.

The Interconnected Integraph. Robert E. Glover and Henry H. Plumb. Jl. A. I. E. E., Sept. 1929, pp. 695-697.

A machine for solving differential equations in two variables is described. The equations may be linear or non-linear and may have variable or constant coefficients. The machine draws out the solution in the form of a curve, together with its derivatives. By altering the connections in various ways, a wide variety of equations may be solved with a limited number of integrating and reflecting elements.

Pyrometer Gipso (Temperaturmessapparat "Gipso"). R. Hase. Metallwirtschaft, Sept. 6, 1929, pp. 878.

Recent improvements on the pyrometer "Gipso" of Hase Co.; Hannover, are reported. Without any protection, the wires of the thermo-couple are immersed directly into the melt, bath, etc. The diameter of the wires is reduced from 5 mm. to 1 mm., the joint is not welded but simply twisted. There is a coil in the case under the galvanometer. Used up wires are cut off and fresh wire is simply drawn out and twisted.—E.F.

New Photographs and Evaluation Apparatus for Colonial Topographic Problems (Neue Aufnahme und Auswertegeraete fuer kolonial-topographische Aufgaben). R. Hugershoff. Bild. u. Luftbild., March, 1929, pp. 24-29.

The "Reinenbildner," a photographic camera for successive snap-shots, the orientation instrument "Quo vadis" which automatically records the route flown, the Aerosimplex for automatic continuous development of location and layer planes are illustrated and explained.—E.F.

Diaphragm Draft Gage as an Aid for Control of Annular Kilns (Membranzugmeser als Hilfsmittel zur Betriebskontrolle am Ringofen). Tonindustrie Zeitung, April 4, 1929, pp. 534-535.

Simple portable draft gages for immediate measurements of drafts in annular kilns are illustrated and explained.—E.F.

Testing the Cooling of Glass (Ueber die Pruefung der Kuehlung von Glas). W. Ewald. Glasindustrie, July 1929, No. 2, pp. 131-134.

An apparatus of the Askania Werke, which measures the phenomenon of double refractions due to internal stresses which characterize the manner of cooling.—E.F.

Testing the Cooling of Glass (Ueber die Pruefung der Kuehlung von Glas). O. Knapp and P. Selenyi. Glasindustrie, Aug. 1929, No. 2, pp. 155-157.

Authors discuss means of drawing conclusions from the observations of the polarization apparatus upon internal stresses in glass.—E.F.

Rapid Balances (Schnellwaagen und Sortierwaagen). Glasindustrie, March, 1929, pp. 60-61.

Scales are discussed and illustrated.—E.F.

Preparation of Mixtures by Means of Modern Balances (Gemengebereitung durch neuzeitliche Waagen). Glasindustrie, Jan., 1929, pp. 5-6.

Three kinds are considered: automatic delivery scales, transportable charging scales and stationary mixing scales.—E.F.

On Scleroscope Hardness, Impact Hardness and Their Relation to Temperature (Ueber die Rueckprunghaerte). F. Rakoski and U. Schylla. Metallwirtschaft, Sept. 27, 1929, pp. 939-942.

Modifications of the Scleroscope Hardness Testing Machine are described with the object to determine rebound values at elevated temperatures. Results from experiments with Al, Cu and Fe are presented in diagrams.—E.F.

The Condenser Chronograph (Der Kondensator Chronograph). H. Rumpff. Zeitschrift fuer das gesammte Schiess und Sprengstoffwesen, Jan., 1929, pp. 13-17.

After considering history and physico-mathematical fundamentals the author introduces an improved instrument for the measurement of detonation velocity over short lengths of explosive, i.e., a fraction of one millionth of a second. The principle represents a time measurement by means of partial condenser discharge produced by a short circuit. The remaining charge of the condenser, measured by a ballistic galvanometer serves as a measurement of the time of short circuit, i.e., of explosion velocity.—E.F.

On the Question of the Determination of the Finest Constituents in Cement (Zur Frage der Bestimmung der feinsten Anteile im Zement). C. Pruessing. Tonindustrie Zeitung, Sept. 19, 1929, p. 1353.

The author calls attention to the recent resolution of the Associated Portland Cement Manufacturers, Ltd., to use the wind-sifter for determinations of grain composition. The instrument is described and critically discussed.

BUYERS' GUIDE

DYNAMIC BALANCING EQUIPMENT
Electrocon Corporation
EARTH CURRENT METERS
Rawson Elec. Inst. Co.
ELECTRIC TELEMETER
Southwark Fdry. & Mach. Co.
EMPLOYEES' "IN AND OUT" TIME RECORDERS
ENGINE INDICATORS
American Instrument Company
Lehmann & Michels
EXTENSOMETER
H. Z. Schniewind
Southwark Fdry. & Mach. Co.
FATIGUE TESTERS
H. Z. Schniewind
FAULT FINDERS
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.
FLASH & BURNING POINT TESTERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.
FLOW METERS
Brown Instrument Co.
Builders Iron Foundry
FLUXMETERS
Leeds & Northrup Co.
Rawson Electrical Instr. Co.
FOLDING TESTER
H. Z. Schniewind
FREQUENCY METERS
Indicating
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Inst. Corp.
Controlling
Leeds & Northrup Co.
Recording
Bristol Company
Leeds & Northrup Co.
FUEL ANALYSIS APPARATUS
Burgess-Parr Co.
FUEL FLOW INDICATOR
Commercial Engg. Labs.
GALVANOMETERS
Brown Instrument Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
GAS ANALYTICAL METERS
Chemical
Tagliabue Mfg. Co., C. J.
Electrical
Brown Instrument Co.
Leeds & Northrup Co.
GAS LEAK INDICATORS
Taylor Instrument Companies
GAS-METERS
Brown Instrument Co.
GAUGE RODS
Tagliabue Mfg. Co., C. J.
GAUGES
Absolute Pressure
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Amplifying
B. C. Ames Co.
Federal Products Corp.
Comparator
B. C. Ames Co.
Federal Products Corp.
Cylinder
B. C. Ames Co.
Federal Products Corp.
Depth
B. C. Ames Co.
Federal Products Corp.
Dial
B. C. Ames Co.
Federal Products Corp.
H. Z. Schniewind
Differential Pressure
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Draft
Bristol Company
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Drill
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Grinding
Federal Products Corp.
Liquid Level
Bristol Company
Brown Instrument Co.
Builders Iron Foundry
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Loss of Head
Brown Instrument Cos.
Builders Iron Foundry
Pitch Diameter
Federal Products Corp.
Pocket
H. Z. Schniewind
Pressure
American Paulin System, Inc.
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Pressure—Temperature
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Pressure & Vacuum
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Profile
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Rain
Taylor Instrument Cos.
Recording Distance
Bristol Company
Brown Instrument Co.
Strain
Southwark Fdry. & Mach. Co.
Thickness
B. C. Ames Co.
H. Z. Schniewind
Volume
Brown Instrument Co.
Water Level for Boilers
Bristol Company
Brown Instrument Co.
Wind
Brown Instrument Co.
Taylor Instrument Companies
GEOPHYSICAL INSTRUMENTS
Akatos, Inc.
GOVERNORS
Pressure
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Pump
Tagliabue Mfg. Co., C. J.
GLASS STRAIN TESTERS
Akatos, Inc.
GREASE TESTING APPARATUS
American Instrument Company
Tagliabue Mfg. Co., C. J.
GROUND DETECTORS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
GROUND-OHMER
Leeds & Northrup Co.
Herman H. Sticht & Company
GYPSUM TESTING INSTRUMENTS
American Instrument Company
H. Z. Schniewind
HARDNESS TESTERS
Akatos, Inc.
Industrial App. & Inst. Co.
H. Z. Schniewind
Wilson-Maeulen Company, Inc.
HARMONIC ANALYZERS
Leeds & Northrup Co.
HIGH VOLTAGE
Measuring Devices
Westinghouse Elec. & Mfg. Co.
Testing Devices
Westinghouse Elec. & Mfg. Co.
HUMIDITY RECORDERS
Wet & Dry Bulb Thermometers
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
HYDROGEN ION METERS—
Indicating
Leeds & Northrup Co.
Rubicon Company
Controlling, Recording
Leeds & Northrup Co.
HYDROMETERS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
HYGROMETERS
Brown Instrument Co.
H. Z. Schniewind
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
IMPACT HARDNESS TESTER
H. Z. Schniewind
IMPACT TESTING MACHINES
Akatos, Inc.
H. Z. Schniewind
Alternating
INDICATORS—See Gauges
INDUCTANCES
Rubicon Company
INSTRUMENT BOOKS
Instruments Publishing Co.
INTEGRAPHS & INTEGRATORS
Leeds & Northrup Co.
INSTRUMENT CALIBRATION AND REPAIRS
Jewell Electrical Instrument Co.
Rubicon Company
INSTRUMENT TRANSFORMERS
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
INSULATION TESTING EQUIPMENT
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
JOB TIMING RECORDERS
KEYS AND SWITCHES
Leeds & Northrup Co.
Rubicon Company
KLYDONOGRAPHS
Westinghouse Elec. & Mfg. Co.
LACTOMETERS
Tagliabue Mfg. Co., C. J.
LENGTH MEASURING MACHINES
H. Z. Schniewind
LEVELS
Centering
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Engineer's, Wye, Precision
Prism
Taylor Instrument Companies
LIME TESTING INSTRUMENTS
American Instrument Company
LOCOMOTIVE INDICATORS
American Instrument Co.
Lehmann & Michels
LUSTER METERS
Akatos, Inc.
MAGNETOMETERS
Rubicon Company

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BUYERS' GUIDE

MANOMETERS
American Paulin System, Inc.
Brown Instrument Co.

MASTER CLOCKS

MEASUREMENT BOOKS
Instruments Publishing Co.

MEGOHMMETERS
Leeds & Northrup Co.
Rubicon Company
Herman H. Sticht and Company

MEGOHM VOLTMETERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

MELTING POINT APPARATUS
Tagliabue Mfg. Co., C. J.

MICROMETERS
H. Z. Schniewind

MICROAMMETERS
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MICROFARADMETERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

MICRO PYROMETERS
Akatos, Inc.

MICROSCOPES

Brinell
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
H. Z. Schniewind

Metallographic
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

Toolmakers'
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

MILLIAMMETERS
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MILLIVOLTMETERS
Bristol Company
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Taylor Instrument Companies
Weston Elecf. Inst. Corp.
Wilson-Maeulen Company, Inc.

MOTION RECORDERS

Mechanical
Bristol Company
Lehmann & Michels

MULTIMETERS
Rawson Elec. Inst. Co.

MULTIPLIERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Elect. Inst. Corp.

NEPHELOMETERS
Akatos, Inc.

OHM METERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.

OIL TESTING APPARATUS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

OIL TESTING EQUIPMENT
American Instrument Company

OPERATION RECORDERS

Electrical
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

ORIFICE METERS
Brown Instrument Co.
Builders Iron Foundry

ORSAT APPARATUS

OSCILLOGRAPHS
Westinghouse Elec. & Mfg. Co.

OXYGEN RECORDERS
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

PANTOGRAPHS

PERFORMANCE METER

PERMEAMETERS
Leeds & Northrup Co.
Rubicon Company

PAPER TESTING INSTRUMENTS
American Instrument Company
H. Z. Schniewind

PERISCOPES
Bausch & Lomb Optical Co.

PHASE INDICATOR
Westinghouse Elec. & Mfg. Co.

PHASE SEQUENCE INDICATOR
Herman H. Sticht Co.

PHOTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Leeds & Northrup Co.

PHYSICAL TESTING MACHINES
Industrial App. & Inst. Co.
Lehmann & Michels
H. Z. Schniewind
Southwark Fdy. & Mach. Co.

PITOT TUBE METER
Brown Instrument Co.

PLANIMETERS

Linear
Brown Instrument Co.
Lehmann & Michels

Radial
Bristol Company

POLARISCOPES
Akatos, Inc.

POSITION RECORDERS
Bristol Company

POTENTIAL DETECTORS
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

POTENTIOMETERS—Indicating
Brown Instrument Co.
Leeds & Northrup Co.
Rubicon Company

Recording & Controlling
Leeds & Northrup Co.

POWER FACTOR METERS
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

POWER FACTOR REGULATORS
Rubicon Company
Westinghouse Elec. & Mfg. Co.

PRESSURE METERS

PROCESS TIMING AND SIGNALING INSTRUMENTS

PROGRAM INSTRUMENTS

PROTRACTOR

Optical
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

PSYCHROMETER

Recording
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

Sling
Taylor Instrument Companies

PYROMETERS

Optical
American Instrument Company
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company

Radiation

Indicating
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies

Recording
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Cos.

Thermo-electric

Immersion
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.

Indicating
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Wilson-Maeulen Company, Inc.

Recording and Controlling
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.

Surface Contact
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies

RADIO SET ANALYZERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

RADIO TUBE CHECKERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

RADIO TEST PANEL
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

REFRACTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.

REGULATORS—See Controls

RELAYS
American Instrument Company
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

REMOTE METERING EQUIPMENT
Bristol Co.
Brown Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

RESISTANCES—Electrical
Leeds & Northrup Co.

RHEOSTATS
Rubicon Company

ROTOSCOPE
Commercial Engg. Labs

RUBBER TESTING INSTRUMENTS
H. Z. Schniewind

SACCHARIMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Taylor Instrument Cos.

SACCHROMETERS
Tagliabue Mfg. Co., C. J.

SALINITY INDICATORS
Rubicon Company

SCALES
H. Z. Schniewind

SCRATCH HARDNESS TESTER

SEISMOGRAPHS
Akatos, Inc.

SHUNT METERS
Builders Iron Foundry

SHUNTS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

SIGNALLING DEVICES—Automatic
Brown Instrument Co.

SLIDE RULES

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BUYERS' GUIDE

SOIL PRESSURE CELLS
American Instrument Company
SPECIAL INSTRUMENTS
American Instrument Company
Burgess-Parr Co.
H. Z. Schniewind
SPECIAL ELECTRICAL INSTRUMENTS
Brown Instrument Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Weston Electrical Inst. Corp.
SPECTROSCOPES
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
SPECTROPHOTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
SPEED INDICATORS
See Tachometers
STANDARD CELLS
Weston Electrical Inst. Corp.
STEEL TAPES
STRAIN GAUGE
Southwark Fdry. & Mach Co.
STRESS INDICATOR
STROBOSCOPES
Commercial Engg. Labs.
SULPHUR DIOXIDE METERS
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
SULPHUR DETERMINATION APPARATUS
Burgess-Parr Co.
Tagliabue Mfg. Co., C. J.
SUNSHINE RECORDERS
Leeds & Northrup Co.
Taylor Instrument Companies
SUPERPRESSURE CATALYST EQUIPMENT
American Instrument Company
SURGE RECORDERS
SYNCHRONIZING FORKS—Electrical
Leeds & Northrup Co.
TACHOSCOPES
Brown Instrument Co.
TACHOMETERS
Bristol Company
Brown Instrument Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
H. Z. Schniewind
Herman H. Sticht & Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
TELESCOPES
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
TENSIOMETERS
American Paulin System, Inc.
TENSOMETER (Huggenberger)
Southwark Fdry. & Mach. Co.
TESTING MACHINE—Universal
H. Z. Schniewind
Southwark Fdry. & Mach. Co.
TEXTILE TESTING INSTRUMENTS
H. Z. Schniewind
THEODOLITES
THERMO-JUNCTIONS (Electric)
Rawson Electrical Instrument Co.
THERMOMETERS
Gas Filled
Bristol Company
Brown Instrument Co.
Taylor Instrument Companies
Tagliabue Mfg. Co., C. J.
Mechanical
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Mercurial
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Resistance
Brown Instrument Co.
Leeds & Northrup Co.
Wilson-Maeulen Co., Inc.
Vapor-Tension
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.
Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
THERMOSTATS
American Instrument Company
American Radiator Company
Bristol Company
Brown Instrument Co.
Taylor Instrument Cos.
Tagliabue Mfg. Co., C. J.
TIME OPERATION RECORDERS
Tagliabue Mfg. Co., C. J.
TIME RECORDERS
Brown Instrument Co.
TIME SWITCHES
Westinghouse Elec. & Mfg. Co.
TIME STAMPS—Automatic
TIME SYSTEMS—Electric
TIMERS
Leeds & Northrup Co.
Rawson Elec. Inst. Co.
TINTOMETER
TORSIOGRAPH
Lehmann & Michels
TRANSITS
Engineer's, Surveyors, Mine, Pocket
Taylor Instrument Companies
TUNING FORKS—Electrically Driven
Rubicon Company
VALVES
Automatic Shut Off
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Balanced
Brown Instrument Co.
Diaphragm
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Electrically Operated
Brown Instrument Co.
Reducing
Tagliabue Mfg. Co., C. J.
Regulating
Brown Instrument Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.
Safety, Fuel Shut-off
Tagliabue Mfg. Co., C. J.
VENTURI METER
Brown Instrument Co.
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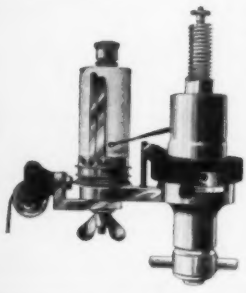

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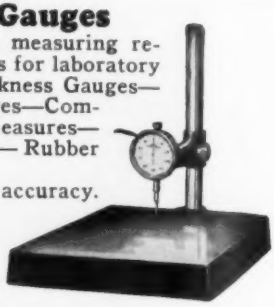

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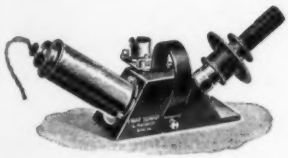

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J. T. NICHOLS. INSTRUMENTS, Vol. 2, No. 12, December 1930, pp. 423-424, 1 fig.

Improvements in balance design are given, and discussed in a general way.

APPLICATIONS OF THE ELECTRIC BALANCE TO THE CONTINUOUS SOLUTION OF MATHEMATICAL FORMULAE.

PERRY A. BORDEN. INSTRUMENTS, Vol. 2, No. 12, December 1929, pp. 425-432, 6 figs.

In a well known method for the transmission and remote measurement of electrical quantities, the mechanical torque developed in an element of the Kelvin balance type is opposed by the reaction due to a regulated current flowing in a d'Arsonval movement mechanically linked to the balance arm. This current being controlled by means of contacts on the arm, the value necessary to restore a state of equilibrium is at all times made proportional to the electrical quantity under measurement in the balance. The system here described amplifies this method, principally through the combination of different types of metering elements and connections, making it applicable to a number of mathematical processes, and thus to the continuous solution of a variety of algebraic and other formulas, which express the relationship of electrical and physical quantities.

MEASUREMENT—INDUSTRIAL & SCIENTIFIC.

DR. WALTER BLOCK. INSTRUMENTS, Vol. 2, No. 12, December 1929, pp. 433-442, 11 figs.

This is the fourth installment of a translation of a German book. This installment considers the shape of measuring units of length, mass and volume.

MEASUREMENT OF AIR FLOW.

E. OWER. INSTRUMENTS, Vol. 2, No. 12, December 1929, pp. 443-454, 5 figs.

Chapter iV. The Flow of Air in Pipes. This is the third installment of a series. The items considered are: The Resistance of a Pipe to the Motion of a Fluid along it; The Characteristics of the Flow in Pipes; Turbulent Flow in Pipes; Velocity Distribution Across a Section.

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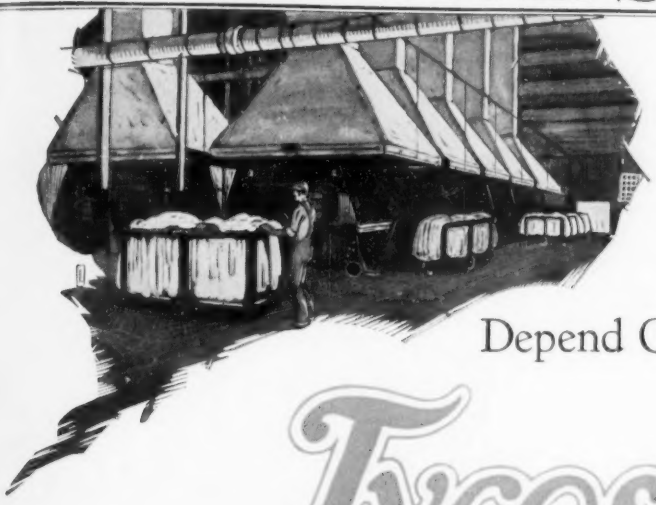

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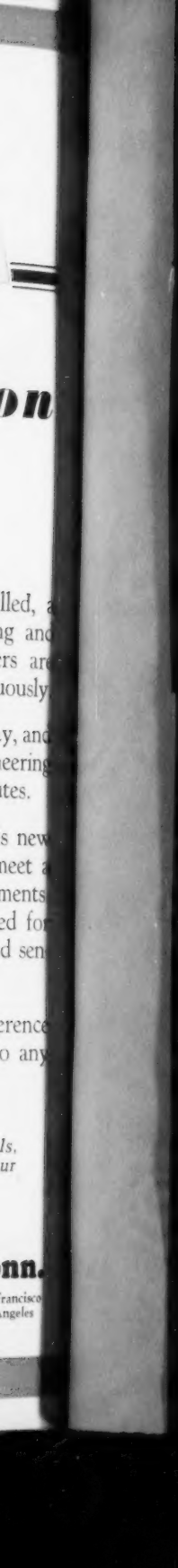
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